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CASSAVA MOSAIC IN SOUTHERN NIGERIA.

By F. D. Golding, m.a., f.r.e.s.

Introduction.

Cassava Mosaic in Nigeria was first recorded by Mr. G. H. Jones, formerly a Mycologist in the Agricultural Department, who, in 1926, found the disease to be prevalent on native farms in the vicinity of Benin and Ijebu Ode. In 1929, the writer carried out investigations with the object of determining whether Mosaic is transmitted from plant to plant by an insect vector; the principal purpose of the present paper is to describe the results of this research.

Geographical Distribution of Cassava Mosaic.

The disease has been reported to occur in the Belgian Congo, Ubangui-Shari, Moyen-Congo, French Cameroon, Nigeria, the Gold Coast, Ivory Coast, Liberia and Sierra Leone. Storey [7] has recorded a virus disease of cassava in East Africa which may be identical with the Mosaic of West and Equatorial Africa.

Local Dispersion of the Disease.

An interesting feature of Cassava Mosaic is that it appears to be spreading inland from the coast in several widely-separated areas. R. P. Tisserant, quoted by Dufrénoy and Hédin [3], states that Mosaic first appeared in Ubangui-Shari as recently as 1924 and that many plantations were affected in the following year; at first the disease appeared to spread along the roads, where cassava plantations occurred in strips. Dufrénoy and Hédin [3] state that Mosaic is found throughout almost all the forest zone of French Cameroon and seems to have spread inland from the coast. Evidence has been collected by Deighton [2] that Mosaic is of comparatively recent introduction in Sierra Leone and that it spreads only very slowly from plant to plant.

In the years 1923 to 1925 the writer made very thorough examinations of the nine square miles of country surrounding Moor Plantation, the headquarters of the Nigerian Agricultural Department about three miles west of Ibadan; no mosaicked cassava plants were seen. The object of the examinations was to determine the alternative food plants of a cotton pest, but the writer is confident that had Mosaic been present on the cassava on native farms in the area, its occurrence would not have escaped notice. Diseased plants were first seen in the Ibadan area in May, 1929, when six were found on a farm adjoining Moor Plantation: about one hundred more mosaicked plants were discovered on three other farms in the area between June and September of that year.

At the time of writing (April 1932) there are few farms in the area west of Ibadan which do not contain diseased plants, although the number of plants is not usually considerable. A survey of the roads in the vicinity of Moor Plantation and Ibadan was made in September, 1929, and it was discovered that Mosaic occurred within six miles of Ibadan in a southerly direction, within seventeen miles to the west and twenty miles to the south-east. Local natives do not remember having seen the disease at Ibadan before 1929, so it is evidently of recent introduction and is apparently spreading slowly northwards. The writer has never found Cassava Mosaic in the Northern Provinces of Nigeria.

Transmission Experiments with Aleurodidæ.

The cassava plant, in most parts of the world, appears to be peculiarly free from the attacks of insect and acarine pests. Dufrénoy and Hédin [3] have recorded the presence of Coccids on the roots of plants in French Cameroon; Deighton [2] states that mites and Aleurodids are common on cassava in most places in Sierra Leone; and Hédin [5] has recently reported the presence of Aphids on cassava leaves in the Ivory Coast. The last-named author is convinced that Aphids operate as vectors of Mosaic, but he does not appear to have proved by experiment that these insects can transmit the disease. It is stated in a Gold Coast report [8] that Mosaic is spread by insects, but no evidence is adduced to prove this statement. The writer is unaware of proof having been obtained experimentally, in any part of Africa, that the disease can be transmitted by an insect vector.

An Aleurodid, *Bemisia* sp., is the only insect which is abundant on cassava in Nigeria and the writer has so far been unable to discover mites, Aphids or Coccids on this crop. *Bemisia* sp. was observed to be particularly numerous on cassava plants at Benin, where mosaic is very prevalent, and also to be common in the vicinity of Ibadan during the rains. A series of experiments was carried out with the object of determining whether these Aleurodids can operate as vectors of Cassava Mosaic; the abundance of these insects and the fact that a species of *Bemisia* had been found to transmit a virus disease of cotton [4] made it appear probable that they would prove to be vectors of Cassava Mosaic.

Before describing the experimental results it is necessary to give a short account of the principal varieties of cassava grown by farmers in the Ibadan district.

Six varieties are recognised, three of which are ' Sweet ' (*Manihot palmata*, var. *Aipi*) and three ' Bitter ' (*Manihot utilissima*); the commonest sweet variety is known to the Yorubas

as ' atu ' and the most frequently grown bitter variety as ' karagba '. Of these two ' karagba ' is the heavier yielder, takes longer to mature and is said to provide ' garri ' or meal of better quality. There appears to be a considerable difference of opinion amongst natives of different localities as to the respective merits of the two varieties, for ' karagba ' is preferred in the Benin and Ibadan districts, and ' atu ' in the vicinity of Abeokuta, while at Ijebu Ode both varieties are grown.

On April 26th, 1929, three diseased ' karagba ' cuttings were planted in a large insect-proof cage; on May 15th fifty adult Aleurodids from mosaicked plants in the field were introduced into the cage to form a stock for the transmission experiments. On July 13th, two 'karagba ' and two ' atu ' cuttings were planted in each of nine cages similar to the original cage; by the 25th, all plants had produced leaves. By this time the Aleurodidæ in the first cage had produced several generations and become numerous; adults from this cage were introduced into five of the nine cages containing healthy plants on the dates shown in Table No. 1.

TABLE No. 1.

No. of Adult Aleurodidæ introduced into cages.

Date.	Cage No. 2.	Cage No. 3.	Cage No. 6.	Cage No. 11.	Cage No. 13.
July 30th	20	20	20	—	—
„ 31st	—	—	—	15	—
August 1st	—	—	—	5	13
„ 2nd	—	—	—	—	17
„ 3rd	15	10	10	10	—
„ 7th	20	25	25	25	25
Totals	55	55	55	55	55

No sign of mosaic disease had appeared by January 30th, 1930, on which date the experiment was terminated. On August 26th, 1929, diseased cuttings from the original cage were planted in three of the cages which had been set aside as controls, it will be remembered that each of these cages contained four healthy plants, two of each variety. On October 16th, fifty adult Aleurodidæ were placed in each of these three cages, which then contained both healthy and mosaicked plants; none of the original twelve healthy plants (four in each cage) exhibited symptoms of mosaic infection on January 30th, 1930. On May 17th, 1929, muslin sleeves were put over shoots of eight ' atu ' and thirty-two ' karagba ' plants growing in the open; three adult Aleurodidæ were introduced into each of fourteen sleeves and six into each of ten, the remaining

twenty-four sleeves were reserved as controls. All the Aleurodidæ were collected from diseased plants, which were then rare in the Ibadan district. On June 5th, the sleeves had to be removed on account of the growth of the shoots, there was no sign of mosaic on the treated plants at that time or subsequently.

It will be seen that all the transmission experiments with *Bemisia* sp. produced negative results.

Effect of Mosaic upon Yield.

The writer has been unable to find in the literature any quantitative data concerning the effect of Mosaic infection upon yield. In December, 1931, it was observed that Mosaic was present in a field of cassava on Moor Plantation. It was decided to utilise this crop for an investigation into the effect of Mosaic upon yield; but, when the field was examined again on February 26th, it was impossible to recognise the diseased from the healthy plants. Atmospheric conditions were exceptionally arid at Ibadan in January, the mean humidity at 9 a.m. being 50.5 per cent as compared with an average figure of seventy-nine per cent (based on the January means for the preceding nineteen years), extensive leaf shedding resulted and there was no sign of Mosaic on the few young leaves remaining on the diseased plants. Unusually heavy rain fell in March, and on the 23rd of that month it was observed that the numerous leaves recently produced by diseased plants were mosaicked. It is evident that the disease only manifests itself during periods of rapid growth.

The field, selected for experimental purposes, consisted of ten plots with a total area of 4.9/10 acres, while the cassava was a mixture of ' karagba ', ' atu ' and two other sweet varieties. The total number of plants in the field was calculated, and a census was made of diseased plants of all varieties and of healthy plants of the three sweet varieties; the approximate number of healthy ' karagba ' plants was determined by subtraction. The results of this census are shown in Table No. 2.

TABLE No. 2.

Variety.	No. of plants.	% mosaicked.
Karagba	8,272	1·97
Atu	1,385	7·58
Eresekosu	120	2·50
Isukankiyan	41	0
Total	9,818	2·76

It was decided to utilise both ' karagba ' and ' atu ' for the investigations. A number of two-branched plants bore mosaicked leaves on only one branch; plants of this type are described as ' partially mosaicked ' below and were harvested separately from ' wholly mosaicked ' plants, i.e., those with diseased leaves on each branch.

It was observed that, as a rule, mosaicked plants occurred in well-marked groups and, as only a limited number of plants was available, it was feared that considerable errors due to soil variation would be encountered if the ordinary sampling method were adopted for the selection of the healthy control plants. It was therefore decided to utilise two sets of controls. In the first set, designated " paired control ", for each diseased or partially diseased plant harvested a healthy plant of similar size and branching was selected, there was seldom a greater distance than four yards between each diseased plant and its control; this method eliminates soil variation to a great extent, but does not take into account the reduction of vegetative growth due to Mosaic. In the second set, designated " random control ", the requisite number of control plants were obtained by harvesting one ' karagba ' plant in every tenth row and one ' atu ' plant in every twentieth row as near as possible to diagonal lines across each plot. Harvesting was carried out between April 6th and 13th, the yields are shown in Table No. 3.

TABLE No. 3.

Type.	No. of plants.	Yield in lbs.	Average yield per plant in lbs.	Depression of yield due to Mosaic.
I. *Karagba.*				
Wholly mosaicked ...	61	$257\frac{3}{8}$	4·22	—
Paired control ...	61	$363\frac{3}{4}$	5·96	29·24%
Random control ...	61	$388\frac{3}{4}$	6·37	33·79%
II. Atu.				
Wholly mosaicked ...	33	$103\frac{3}{8}$	3·13	—
Paired control ...	33	$123\frac{3}{4}$	3·75	16·46%
Random control ...	33	$181\frac{1}{2}$	5·50	43·04%
III. Karagba.				
Partially mosaicked ...	30	$210\frac{1}{4}$	7·01	—
Paired control ...	30	$204\frac{1}{4}$	6·81	Nil.
Random control ..	...	...	6·37	Nil.
IV. Atu.				
Partially mosaicked ...	14	$86\frac{1}{4}$	6·16	—
Paired control ...	14	$79\frac{5}{8}$	5·69	Nil.
Random control ...	...	...	5·50	Nil.

The following conclusions are drawn from the results tabulated above :—

(*a*) The yield of plants with mosaicked leaves on all their branches is about thirty per cent lower than that of healthy plants.

(*b*) Two-branched plants with mosaicked leaves on only one branch have recently become infected as there is no reduction in their yield.

(*c*) Since the paired controls for each variety, when wholly diseased, yielded less than the corresponding random controls; Mosaic infection evidently reduces vegetative growth. The paired controls for each variety, when partially diseased, yielded slightly more than the corresponding random controls, so it appears that infection occurred too late to effect the vegetative growth of the partially diseased plants. During harvesting it was noticed that the average size of partially diseased plants appeared to be greater than that of wholly mosaicked individuals; but, owing to the diverse habits of growth, no satisfactory method of measurement could be devised.

Control.

(*a*) *Varietal Resistance to Mosaic.*

The most hopeful means of control appears to be the utilisation of varieties of cassava exhibiting a marked resistance, or even immunity, to the disease; a resistant variety, known as Senegali, has been found in French Cameroon [3]. In the Gold Coast [1] a large series of varieties is being studied from the point of view of resistance to Mosaic. It is obvious that the problem of control lies in the sphere of the plant breeder rather than in that of the entomologist; the following notes are given in the hope that they may be of assistance to botanical workers in Nigeria, who may study the control of Cassava Mosaic in the future.

In May, 1929, the writer arranged for a number of healthy cuttings of both ' atu ' and ' karagba ' from Ibadan to be planted contiguously with infected local cuttings at Benin. The Benin cassava is a variety of *M. utilissima* and appears to be particularly susceptible to Mosaic. The cassava was planted in batteries each containing 104 plants, five batteries of Benin cuttings were alternated with two of each of the Ibadan varieties. The cuttings were planted on May 10th, 1929, and as many of the Benin plants died, it was necessary to supply the five Benin cassava plots on June 11th. The spread of the Mosaic during the first four months after planting is shown in Table No. 4.

TABLE No. 4.

104 CUTTINGS PLANTED IN EACH PLOT ON MAY 10TH, 1929.
PERCENTAGE OR MOSAICKED PLANTS ON :—

Plot No.	Variety.	June 10th.	July 10th.	August 10th.	September 10th.
1.	Benin	45	81	88	94
2.	Karagba	1	32	70	88
3.	Benin	53	81	93	98
4.	Atu	0	9	30	59
5.	Benin	49	89	91	97
6.	Karagba	1	36	69	88
7.	Benin	47	70	84	98
8.	Atu	0	15	26	42
9.	Benin	49	61	90	95

It will be seen that the healthy Ibadan varieties very rapidly became mosaicked when planted in close contact with alternating plots of diseased Benin plants. Mr. G. W. Briggs, who kindly carried out the observations on the writer's behalf, stated that in addition to the lower percentage of 'atu' plants affected, the disease appeared to be less virulent to this variety and did not appreciably retard the growth of the plants which developed mosaic symptoms. Mr. Briggs also stated that the preference of the local natives for 'bitter' cassava was owing to the fact that the tubers of 'atu' cannot be stored for any length of time and only inferior 'garri' can be prepared from its roots. The plots were harvested on December 24th, 1930, and the writer is indebted to Mr. J. L. B. Kincaid for the yield figures shown in Table No. 5.

TABLE No. 5.

YIELD : WEIGHT OF ROOTS AS HARVESTED IN DRY CONDITION.

Plot No.	Variety.	Yield in lb. per acre.	Increase (+) or decrease (−) compared with mean of adjacent controls.
1.	Benin	10,724	
2.	Karagba	18,424	+ 9,886
3.	Benin	6,352	
4.	Atu	41,304	+ 33,962
5.	Benin	8,332	
6.	Karagba	16,116	+ 8,390
7.	Benin	7,120	
8.	Atu	38,828	+ 28,298
9.	Benin	13,940	

Average of five plots Benin Cassava 9,294 lb. per acre.
Average difference of two plots 'Karagba' + 9,138 ± 2,989.
" " " 'Atu' + 31,130 ± 2,989.

It will be seen that the yields of both Ibadan varieties were markedly greater than that of Benin cassava. It is probable that the low yield of Benin variety was due to the severity of Mosaic on the plots of indigenous cassava. Although the Ibadan varieties gave a much higher yield than the local variety at Benin, it is improbable that 'atu' would find favour with the local farmers, while 'karagba' showed little resistance to Mosaic, and it is probable that, in the course of several years, its yield would be considerably depressed.

(*b*) *Roguing of infected plants.*

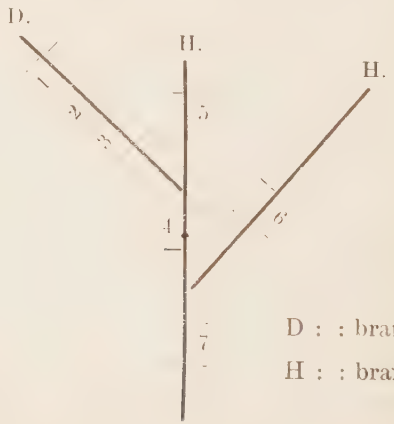
This method of control is obviously impracticable over large areas in Southern Nigeria, where the dense vegetation would preclude the possibility of eradicating more than a very small proportion of diseased plants. When Mosaic was first observed in the vicinity of Moor Plantation all the diseased plants were uprooted and burned; the area was thoroughly examined at intervals between May and September, and, by the end of the last-named month, few if any mosaicked plants remained. In spite of this roguing, Mosaic has now appeared on most of the farms in the vicinity of Moor Plantation.

(*c*) *The Use of Seed for Planting.*

There is no doubt that the spread of disease is often assisted by the native farmer utilising cuttings from mosaicked plants. To obviate this Joly [5] has suggested that the farmers in French Cameroon should be encouraged to use seed instead of cuttings.

Spread of Mosaic through the Plant.

It was frequently noticed that only one branch of an infected plant bore mosaicked leaves. It may be of interest to record the results of an experiment in which cuttings from a plant of this type were planted and kept under observation for four and a half months. The positions from which the various cuttings were taken are shown in the following diagram.



D : : branch bearing diseased leaves.

H : : branch bearing healthy leaves.

The seven cuttings were planted in an insect-proof cage on September 13th, 1929; when the cuttings were taken, Nos. 1 and 2 bore mosaicked leaves and Nos. 3, 5 and 6 bore healthy leaves. All leaves were removed before the cuttings were planted. By September 30th, Nos. 2, 3 and 7 had produced diseased leaves; by October 8th, No. 4 had also produced mosaicked leaves. Cutting No. 1 died. From September to the end of the experiment on January 30th, 1930, Nos 5 and 6 showed no signs of Mosaic infection. It seems probable that infection occurred through the leaves of the deceased branch rather than from the roots of the plant. It was observed that when diseased cuttings were planted all the leaves of the resultant plants were mosaicked.

Summary.

(*a*) A series of transmission experiments with an Aleurodid, *Bemisia* sp., gave negative results; this is the only insect which is abundant on cassava in south-western Nigeria.

(*b*) Plants with mosaicked leaves on all branches yielded about thirty per cent less than healthy plants. Two-branched plants with diseased leaves on one branch yielded as much as healthy plants and were apparently recently infected.

(*c*) Plots of two Ibadan varieties of cassava were grown contiguously with plots containing infected plants of a local variety at Benin, where Mosaic is prevalent. The introduced varieties yielded, respectively, about twice and four times as much as the Benin cassava; but eighty-eight per cent of one variety and from forty-two to fifty-nine per cent of the other became mosaicked within four months of planting.

Acknowledgments.

The writer wishes to express his indebtedness to Mr. G. W. Briggs for carrying out the variety test at Benin on his behalf; to Mr. J. L. B. Kincaid for determining the yields of the experimental plots at that place; and to Mr. J. West for helpful criticism.

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(Received for publication on 15/4/32.)

Author's Note. The Aleurodid, which has lately been described as *Bemisia nigeriensis*, Corbett, *sp. novum*, has now been proved by the writer to be a vector of Cassava Mosaic.

F.D.G., 23*rd April*, 1936.

FURTHER EXPERIMENTS ON THE FERMENTATION OF CACAO.

By T. Laycock, a.r.c.s., d.i.c.

In a previous article (1) it was shown that samples of cacao free from insufficiently-fermented beans could be obtained by very unlaborious methods of fermentation. Since writing that article we have obtained from Messrs. Cadbury a report by their specialists on the samples Nos. 1 to 18 which were described in Table II of the article mentioned. The salient point in the report was that frequency of changes during the fermentation makes much less difference to the final cocoa produced than does the state of the beans when picked. The samples of very ripe beans gave rise to a product of better colour and with looser cotyledons than did those samples harvested early in the season. The worst sample in their opinion was No. 9 which was changed twice daily whilst Numbers 8, 10 and 18 were regarded as being abnormally dark in colour; and all these were samples changed once daily during fermentation. The best samples in their opinion were Numbers 13 to 18 and these were from very ripe beans.

It would appear therefore that, from the manufacturers' point of view, a good sample fulfilling their requirements could be obtained by unlaborious methods provided that the beans were fully mature. Also, as these commended samples were fermented in boxes, in large and also in small baskets, some were small samples such as the average farmer would deal with. Therefore, providing that the beans are fully mature, it is not necessary that there should be large quantities in order to obtain a cured product which would satisfy the manufacturers' requirements.

On the other hand, these samples were also reported upon by two firms of brokers and there were striking differences in their reports and that of the specialist. In fact, of the last eight lots which had been commended by the specialist, one broker wrote that he did not care very much for them, and the other considered them to be over-fermented. There was nothing definite in these brokers' opinions as to whether they preferred " changed twice daily " or " once daily " and, from their point of view, there would appear to be nothing consistent in the effects of these treatments. Confronted with such vastly contrary reports on these samples of cacao from the two authorities qualified to judge the value of the product at home, the Director of Agriculture minuted, " It is evident that we must be mainly guided by the brokers' opinion which represents that of the general market. If the manufacturers

cannot educate the market, we cannot. Further, the lesser degree of fermentation which the brokers prefer has the advantage of giving beans that are less likely to mould and of being less a laborious process."

It seemed evident, from a study of these reports, that a process of fermentation which involves only two or three changes would give a satisfactory result from the brokers' point of view; and with this object in view the following series of fermentations was carried out :—

(*a*) Changed on 2nd, 3rd and 5th days.
(*b*) ,, ,, 2nd and 4th days.
(*c*) ,, ,, 2nd, 3rd and 4th days.
(*d*) ,, ,, 2nd and 3rd days.
(*e*) ,, once daily.

They were all fermented in small baskets and the quantity of beans was such as would be dealt with by the average farmer during a fermentation. Samples were taken out of the baskets at the end of the sixth, seventh, and eighth day, and the seven days' fermented was considered just right. All the samples on examination were regarded as being of first grade quality.

Samples of the seven days' fermented were forwarded to Messrs. Cadbury with a request for a report by their specialists and by their brokers.

These reports again showed marked differences of opinion and, whilst on the scientific side they found important differences, commercially all the samples were classed together. The brokers refer to them as being quite sweet and well cured and state that there was little to choose between the lots. Mr. Knapp, Chief Chemist of Cadbury Brothers Limited, in the course of his report on these samples, writes :—

" It would appear that provided Nigerian cacao is up to a " certain standard, it is worth a certain price, and small variations " and advances beyond that standard do not affect the price. " Whilst this applies to individual parcels, I assume that as the " standard in the district rises, the price must rise also, although " it may show a considerable lag. The scientific report does not " show, as far as I can see, any advantage in turning once daily; " at the same time one inclines to think that this is the best " practice, although, of course, the necessity for frequent turning " cannot be anything like so great with small quantities as with " large quantities."

One point in the reports should be especially mentioned which is that, in both the commercial and the scientific reports, preference is shown for lots (*c*) and (*d*) which received three and two changes respectively.

Now the writer is of the opinion that, owing to the conservatism which exists within the trade, and which to a certain extent arbitrarily fixes values according to the country of origin and irrespective of the real value of the cacao, the price for well-fermented cacao will lag for a very considerable time. Therefore, unless some standardised methods are employed in assessing the value of the produce, then Nigerian cacao, no matter how well it is prepared, will never receive the same price as would similar cacao from a country of more favoured reputation.

It would appear that the unlaborious methods just outlined will give a product which satisfies the present requirements of the home market and which is of Grade I quality according to our "Produce Inspection Standard."

All the fermentations which have been dealt with thus far were of cacaos harvested on Moor Plantation and presumably from mature pods. It was considered that the series of fermentations would not be complete until methods carried out on native farms had been studied. The farms selected were those on which control measures for black pod diseases are being carried out. The usual practice of the farmers is to remove all beans, whether good or diseased, and place in a heap on banana leaves which are also used to cover the beans; and it is then left unchanged for about four days. On certain farms they were placed in pits and left undisturbed as before.

In experiments on the native farms the following series of fermentations was carried out:—

(1) Ordinary farmers' sample in pits unchanged.
(2) do. in heaps unchanged.
(3) Full ripe beans in pits unchanged.
(4) do. heaps unchanged.
(5) do. pits changed daily.
(6) do. pits changed 2nd, 3rd and 4th day.
(7) do. pits changed 2nd, and 3rd day.
(8) do. heaps changed daily.
(9) do. heaps changed 2nd, 3rd and 4th day.
(10) do. heaps changed 2nd and 3rd day.

The pits were lined with banana leaves and the cacao well covered.

The whole were fermented for a period of from six to six and a half days with the exception of numbers three and four which were taken out at the end of four and a half, and three and a half days respectively because white ants had entered the mass of cacao and were interfering with the fermentation process.

Three different lots of these samples of cacao were cut and examined and, if based on the department's grading, they would all have ranked as Grade I. The first two samples, however, were much more purple than any of the others but, apart from two per cent and three per cent of unfermented beans respectively, they had a good break.

The following table gives the percentage of unfermented, purple, and chocolate beans.

TABLE I. FERMENTATIONS ON NATIVE FARMS.

Nature of Fermentation.	Percentage of insufficiently fermented beans.	Percentage of purple beans.	Percentage of chocolate beans.
(1) Ordinary Farmer's sample in pits unchanged	2	48	50
(2) Ordinary Farmer's sample in heap unchanged	3	39	58
(3) Full ripe beans in pits unchanged. Fermented for four-and-a-half days only	...	24	76
(4) Fully ripe beans in heaps unchanged; fermented three-and-a-half days only	...	24	76
(5) Fully ripe beans in pits changed daily .	1	22	77
(6) Fully ripe beans in pits changed 2nd, 3rd and 4th day	...	17	83
(7) Full ripe beans in pits changed 2nd and 3rd day	...	10	90
(8) Full ripe beans in heaps changed daily ...	...	11	89
(9) Full ripe beans in heaps changed 2nd, 3rd and 4th day	1	24	75
(10) Full ripe beans in heaps changed 2nd and 3rd day	...	17	83

It ought to be emphasised that even among those beans classified as chocolate there was, in every case, a certain tinge of purple which varied slightly in the different fermentations. Judged on the degree of the chocolate colour obtained one considers the fermentations in heaps to be better than in pits. As regards the effect of the number of changes given, there was little to choose between the samples changed daily, changed three times and changed twice. One inclines to the opinion that daily changes are unnecessary and that the sample which only received two changes throughout the process is of a sufficiently high grade to satisfy our Grade I standard.

Mr. A. W. Knapp, Chemist of Cadbury Brothers Limited, visited us in December and examined the above samples of cacao. He stated that in some fermentation experiments which he had recently carried out whilst on the Gold Coast, in the course of

which the beans were changed at the end of forty-eight and ninety-six hours, he obtained a product which he regarded as sufficiently fermented. To substantiate this another series of fermentations was carried out on the native farms, and for this similar weights of cacao were taken and all were fermented for six days.

The following series of fermentations was set up :—

(1) Changed daily in pits.
(2) Changed daily in heaps.
(3) Changed after forty-eight and ninety-six hours in pits.
(4) Changed after forty-eight and ninety-six hours in heaps.
(5) Ordinary farmer's sample in pits unchanged.
(6) Ordinary farmer's sample in heaps unchanged.

These samples were examined after drying and gave additional support to the statement already made, namely, that much more thorough fermentation takes place in heaps than in pits. There was also little to choose as regards break and colour between the sample in heaps changed daily and that changed after forty-eight and ninety-six hours only. One has no hesitation in stating that the fermentation with only two changes in heaps gives a really superior first grade product and in the event of any propaganda work being carried out this is the obvious method to be advocated.

Below are given the percentages of insufficiently-fermented, purple, and chocolate beans in all the samples. The figures are the mean of three counts.

Table 2. Fermentations on Native Farms.

Nature of Fermentation.	Insufficiently fermented.	Purple.	Chocolate.
1. Change daily in pits	6	27	67
2. Changed daily in heaps	...	3	97
3. Changed after 48 hours and 96 hours in pits	7	25	68
4. Changed after 48 hours and 96 hours in heaps	...	5	95
5. Ordinary Farmer's sample unchanged in pits	3	28	69
6. Ordinary Farmer's sample unchanged in heaps	4	25	71

It will be noted that there was quite a high percentage of fermented beans in both pits and heaps even when no changes were given. In both cases the fermenting beans were very carefully and completely covered with banana leaves and when examined just before they were removed for drying they were comparatively free of moulds. There was no slatey bean in any of these samples.

One unexpected result was obtained during these fermentation experiments and must be recorded. With the object of testing whether unripe beans would become chocolate on fermenting, a sample of beans was selected from green immature pods. They were white, owing to the pulp cells not being mature, and were difficult to remove from the pods. They were wrapped in muslin and fermented in the centre of a bulk quantity of normal beans. On cutting after eight days' fermenting and drying, all the beans were of a chocolate colour and good break. In a repeat experiment eighteen per cent of the beans were purple and the rest chocolate; but of these latter thirty per cent were very light chocolate in colour and had a close cut and fifty-two per cent were dark chocolate with a good break. A further picking of unripe beans was made and these were put to ferment by themselves and in this case forty per cent of the beans were purple and the rest chocolate in colour. Contrary to what one would expect, these experiments show that even very unripe beans may change and become definitely of a chocolate colour. Whilst the general conclusion remains valid namely, that the riper the bean the more certain is one to obtain a chocolate colour on fermenting, yet it now must be admitted that even unripe beans may also give a chocolate-coloured product.

The fact that purple beans occur so frequently in average samples of cacao, is not solely a result of the presence of unripe beans within such samples and, until more is known of the complex actions and reactions which occur during fermentation, and which apparently govern the oxidation of the tannin which is responsible for the change in colour of the beans, we shall not be able to supply a satisfactory explanation.

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A NOTE ON BENISEED AND ADULTERANTS.

By E. H. G. Smith, m.a.

Beniseed (*Sesamum indicum* Linn :) is an important export crop in the Benue Province of Northern Nigeria. During the year 1930, samples of seed from this area, collected by the Superintendents of Agriculture, Yandev, were grown at Ibadan so that the types could be studied and the species determined. This investigation was also of importance on account of the black seed, with which commercial shipments of beniseed to Europe were found to be adulterated, and which lowered the oil content of the shipments. Holland [1] has described three members of the Pedaliaceæ, *S. indicum*, *Sesamum radiatum* Schumach and *Ceratotheca sesamoides* Endl., as widely distributed in Nigeria; all three, together with what is judged to be a hybrid between *S. indicum* and *S. radiatum*, have been raised from the samples of seed grown. Specimens of these were forwarded to Kew, and the correctness of the identifications has been confirmed. Certain samples of seed were also analysed by the Agricultural Chemists.

Preliminary Work.

A sample of "black beniseed" received from Wukari in 1928 was found by Mr. D. Manlove to contain 36.4 per cent of oil. This percentage is far less than that usually found in the seeds of *S. indicum*, which according to Bolton [2] contain from forty-eight to fifty-four per cent of oil. It was therefore suggested by Mr. C. H. Wright that this sample was not the seed of *S. indicum*, but was the seed of a closely allied species, either *S. radiatum* or *C. sesamoides*.

1930 Season.

In 1930 the samples of seed obtained were grown. Three samples, numbers 1, 2 and 3, were obtained by the Superintendents of Agriculture, Yandev, and two other samples, denoted as grades 2 and 3, through the agency of a commercial firm.

These samples are now described :—

Sample 1.—Sample 1 was stated to be the standard beniseed grown by the Zumperi hill tribes to the east of the Benue Province, where the predominant seed colour is said to be yellow. The seeds of this sample, and the resulting plants with one exception, a suspected hybrid, were all typical *S. indicum*.

(i) Majority of sample yellow seeds produced yellow or brownish seeds.

(ii) Minority of sample white seeds—produced white or yellow seeds.

(iii) A few brown seeds—produced brown or yellow seeds. The hybrid was produced from a brown seed.

Sample 2.—Sample 2 was forwarded as an example of *S. radiatum*. It was also obtained from the Zumperi hill farmers who are stated to eat the leaves but not the seeds of this species. The black seeds, however, become mixed in the commercial beniseed sold in the markets. The seeds of this sample, and the resulting plants, were all typical *S. radiatum*.

(i) Majority of sample black seeds—produced black and dark brown seeds.

(ii) A few dark brown seeds—produced dark brown and black seeds.

Sample 3.—Sample 3 was received as typical of a commercial sample of beniseed as exported to Europe from the Benue Province. It was collected at Donga market to the north-east of this Province. The majority of the sample consisted of yellow, with many white, and a few brown, seeds. The white seeded type is reported to be grown by the Munshi people to the west of Donga and the yellow type by the Zumperi hill tribes to the south-east of this town. Both types are bulked by the merchants for export. The seed of this sample and the resulting plants were typical *S. indicum*. The behaviour of seed colour was as described for sample 1.

In the Gongola valley beniseed is reported to have been purchased by the merchants in three grades. The river Gongola is an important tributary of the Benue and feeds the latter from a northerly direction; the confluence is in Adamawa Province.

Grade 1.—Grade 1, of which no sample was received, was said to be similar to samples 1 and 3, that is typical *S. indicum* with, possibly, some slight admixture.

Grade 2.—Grade 2 was found to consist mainly of flat black seeds of *C. sesamoides* but included a general mixture in which were found flat dark grey, dark brown and creamy yellow seeds of *C. sesamoides*, some intermediate light and dark brown seed of the suspected hybrid, and white seeds of *S. indicum*.

C. sesamoides:—

(i) Black seeds - produced black, dark grey and dark brown seeds.

(ii) Dark grey seeds—produced dark grey and dark brown seeds.

(iii) Dark brown seeds - produced dark brown, black and dark grey seeds.

(iv) Creamy yellow seeds—produced creamy yellow, black and dark grey seeds.

All the above seeds, and the resulting plants, were typical *C. sesamoides*. On analysis, Mr. D. Manlove found the seeds of *C. sesamoides* to contain 37.3 per cent of oil, and the oil to give a negative reaction to the Baudouin test. Bolton (lit. cit) gives the proportion of oil in the seed as 35.5 per cent. This author also states that the oil is known to be edible and could be used for the same purpose as sesamé oil.

The plants produced by the intermediate light and dark brown seeds, the suspected hybrids, appeared to be identical vegetatively with *S. radiatum*. The same characteristic unpleasant odour, emitted by the whole plant, was observed as is recorded by Thiselton-Dyer [3]. The seeds produced were light and dark brown in colour and identical in appearance with those sown. Mr. J. Hutchinson and Dr. J. M. Dalziel of Kew, who examined specimens, were of the opinion that probably these were hybrids of *S. radiatum* Schum. and *S. indicum* Linn. Commenting on the seeds, these authorities observed that the seeds are almost intermediate in size and surface characters, some being smooth and pale, as in *S. indicum* Linn., others dark brown with a slight wrinkling towards the margin, approaching *S. radiatum* Schum.

The white seed typical of *S. indicum* produced plants of this species with white and yellow seeds.

Grade 3.—Grade 3 consisted of a similar mixture to grade 2 with the exception that no seed of *S. indicum* was found. A larger proportion of *C. sesamoides* was observed and the majority of the seeds of this species were, for grade 3, a creamy yellow in colour. The seeds, and the resulting plants, of the suspected hybrid were identical with those described for grade 2. The behaviour of seed colour of the *C. sesamoides* was somewhat different to that recorded for grade 2 and no dark brown seeds were found :—

(i) Creamy yellow seeds—produced creamy yellow seeds.
(ii) Black seeds produced black and creamy yellow seeds.
(iii) Dark grey seeds—produced dark grey and creamy yellow seeds.

All the above seeds, and the resulting plants, were typical *C. sesamoides*.

Appearance in the Field.

The three species described in this note and the suspected hybrid may be readily distinguished in the seed and in the plant, with the exception of *S. radiatum* and the suspected hybrid, which when grown at Ibadan were identical vegetatively.

The following characteristics are recorded :—

S. indicum.—Height four feet or more. Lower leaves three partite or undivided, upper lanceolate, slightly hairy. Corolla whitish and tinged pink or purple. Capsule short beak. Seeds perfectly smooth, small; white, yellow or pale brown in colour.

S. radiatum.—Height four feet or more. Lower leaves ovate, upper lanceolate, slightly hairy. Corolla purple. Capsule short broad beak. Seeds radially ridged, one margin is rounded, the other acute; colour black or dark brown. The seeds are larger than those of *S. indicum*. The whole plant emits a characteristic unpleasant odour.

C. sesamoides.—Semi-procumbent or height up to two feet. Leaves ovate, dentate, hairy. Corolla lilac, throat tinged yellow, purple lines. Capsule two small horns, no beak. Seeds broad, flat; sharp angular margins, radiately wrinkled; colour black, creamy yellow, dark grey or dark brown.

Suspected Hybrid of S. indicum and S. radiatum.—Vegetative characters identical with those of *S. radiatum*. Seeds pear shaped, almost intermediate in size and surface characters between those of *S. indicum* and *S. radiatum*. Some smooth, others wrinkled towards the margin; colour light or dark brown.

For further details of the systemetry of the Nigerian members of the Pedaliaceæ *see* Thiselton-Dyer (lit. cit.) and Hutchinson and Dalziel [4].

Discussion of Results.

Samples of beniseed (*S. indicum*) and a sample of *S. radiatum* from the Benue Province have been described. Commercial grades 2 and 3, of the three grades in which beniseed was said to be purchased in the Gongola valley, have been examined and found to consist mainly of *C. sesamoides*, with a proportion of the seed of the suspected hybrid; and, in grade 2 alone, a trace of *S. indicum*. If Bolton, as quoted, is correct, *C. sesamoides* should be saleable in European markets provided the lower oil content of the seed of this species, as compared to that of the true beniseed (*S. indicum*), can profitably bear the transport and other charges involved. What is judged to be a hybrid between *S. indicum* and *S. radiatum* has been obtained and described. No true black seeded beniseed (*S. indicum*), as described by Watt [3] and other authors, has been found. The " black beniseed " grown at Takum has been shown

to be *S. radiatum*. Mr. D. Manlove found the oil content of the seed of this species to be 32.3 per cent, whereas that of the *S. indicum* seed analysed was 54.1 per cent. The oil of both these species gave a positive reaction to the Baudouin test. It seems probable that the so-called " black beniseed ", which may be found in commercial parcels of beniseed, is usually *S. radiatum* but it is possible that this term might be used for the black seeds of *C. sesamoides*. Notes have been included to facilitate the recognition of these species both in the plant and in the seed. With the exception of plants of *S. radiatum* and of the suspected hybrid, all have been shown to be readily distinguishable from each other.

Acknowledgments.

It has fallen to the writer to record the observations and results of several workers. In particular, acknowledgment is made of the work of the Superintendents of Agriculture, Yandev, who have collected both samples and information. Further, the writer is indebted to Mr. J. Hutchinson and Dr. J. M. Dalziel, of Kew, for a valuable report on the specimens submitted; to Mr. C. H. Wright, Senior Agricultural Chemist, for advice, and for supplying the details of the preliminary work undertaken; and to Mr. D. Manlove, Agricultural Chemist, for kindly determining the oil contents, and the reactions to the Baudouin test.

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COTTON SEED DISINFECTION EXPERIMENTS TO CONTROL BACTERIAL DISEASES OF THE COTTON PLANT.

By T. Laycock, A.R.C.S., D.I.C.

Considerable work has been done in Nigeria in attempting to control diseases produced by *Bacterium Malvacearum*. E.F.S. This organism, by stomatal infection, gives rise to water soaked angular spots on the leaves of the cotton plant. These lesions are limited by the small leaf veins and are found dotted over the leaf lamina and also aggregated along the sides of the main veins and in intimate contact with these. Defoliation is usually accelerated in the case of affected plants. Lesions also occur on the stems of the plant though this form of the disease is not so common as the leaf infection; when present however it does much damage as the stems are ringed and destroyed. The disease is also in evidence on the cotton bolls and lesions in this position are usually invaded by other fungi such as *Fusarium* sp. and *Colletotrichum gossypii* (Southw.) when the bolls may become completely rotted.

Distribution of the Disease.

Bacterial diseases are practically absent in the extreme southern part of the Protectorate which fact is accounted for by the higher temperature both of soil and air which obtains there. Even in the Oyo Province the disease is only of slight importance economically. Several surveys of the factors inhibiting the development of cotton in various parts of Nigeria have been carried out. In the Oyo Province work has been done at Moor Plantation, Oyo, Ilugun and Adio in which places disease damage has been assessed. These assessments emphasise the comparative unimportance of the disease in this Province. In the middle and northern cotton belts the position is different and the disease appears of economic importance. Several surveys have been carried out by both Golding and Lean at Ilorin and Bode Sadu in the Ilorin Province; at Badeggi (near Bida) in the Niger Province and at Yandev in the Benue Province, and these stress the importance of bacterial diseases in these areas. Golding [1] at Ilorin in the season 1928-29 stated that bacterial disease was the principal pest of cotton and regarded it as the principal cause of shedding of flowers and bolls. At Badeggi he found that bacterial lesions were encountered more frequently than those of any other factor on boll sheds. At Bode Sadu in the season 1929-30 he found bacterial lesions to be prevalent. In the northern belt no detailed

surveys have been carried out. Mr. G. H. Jones when Mycologist in this department toured the northern cotton belt and reported that the disease was continuously active on the plant body until very near the peak of the flowering curve. Further, even after the rains have stopped and even after two or three days of mild harmattan it was found that the disease was still able to spread over the individual plant by the medium of the dew formed at night. In 1926 Jones gave a rough estimate of fifteen to twenty per cent loss of leaf area due to the disease in the Samaru district; and he stated that at Daudawa the disease was even more severe it being not uncommon for the whole plant to be killed. He considered that it was also responsible for the apparently large amount of shedding and boll mummifying that was occurring. He was convinced, as a result of his visit to the North, that in this region the disease was of major importance and that, were it absent, the yield of cotton would probably be considerably increased.

Transmission of Bacterial Diseases.

Bacterial diseases of cotton are transmitted by the seed, a fact which has been well established for a number of years. American workers based their methods of control on this fact and attempted to eradicate the disease by first disinfecting the seed prior to planting. Duggar invented a method of disinfecting cotton seed by treating with concentrated sulphuric acid and subsequently washing in distilled water. Other methods included a further treatment with mercuric chloride and washing in water. The sulphuric acid treatment has the advantage that it actually stimulates the seeds and germination is much more rapid in seeds thus treated. There is, however, a doubt as to whether the seed is completely disinfected for after treatment there is frequently left a small tuft of fuzz at the micropylar end of the seed. In the season 1923-24 we tried the method of Faulwether, which combines sulphuric acid and mercuric chloride treatments, on seed of Meko cotton: a one-tenth acre plot of cotton from such treated seed was completely free from disease.

It has already been explained that the disease is of little importance in the southern belt and it must be admitted that there was very little disease on plants from untreated seed during this particular season. Still, the experiment would appear to support the view that the bacterium is present only on the outside of the seed. Recently, however, Archibald [2] figured the bacteria in the tissue of the cotyledons. No evidence is given as to whether such seed were viable. Massee [3] confirmed Archibald's investigations but in his latest paper [4] he made further examinations of seed for evidence of internal infection and got negative results and states that the seed in which internal infection had been found

previously was from very badly attacked plants. Hansford, Nye and Briggs [3] state that "all experience with the disease under Uganda conditions indicates that seed infection is almost entirely limited to the exterior of the seed." As will be shown our experiment lends support to this view.

Experimental Work on Cotton Seed Disinfection.

It was obvious that to test the effect of any method of seed disinfection the treated seed should be planted in an area where the climatic conditions were favourable for the growth of the bacterium and in the season 1928 Jones carried out some experiments at Ilorin making both qualitative and quantitative tests. These were only undertaken after considerable preliminary work both at Rothamsted and on Moor Plantation at which latter place Jones was in collaboration with Mr. A. C. Barnes at that time Chemist in the Agricultural Department.

The final outcome of this experimental work was that qualitative tests were carried out using various methods of seed treatment. The treated seed was sown in isolated one-tenth acre plots surrounded by high grass. A control plot from untreated seed was also included. The following methods of treatment were carried out qualitatively.

Plot A.—Seed treated with sulphuric acid for twenty minutes, washed and dried in a current of air at 50° C for one hour.

Plot B.—Weighed quantities of seed were placed in an open glass dish in a solution of one per cent of germisan and 0.2 per cent of yellow soap; they were well mixed and stirred in this solution for ten minutes, squeezed slightly, and dried back to the original weight in one hour. One kilogram of seed absorbed 700 c.c. of this solution.

Plot C.—Seeds were placed in a vacuum desiccator in one per cent germisan in water and covered with a weighted gauze. Air was pumped out until a pressure of 3.3 cms. of mercury was reached (*i.e.* 71.5 cms. of mercury in a manometer). The vacuum was then broken and the seeds allowed to remain in the solution for three minutes. They were then squeezed slightly and dried to their original weight in ninety minutes.

Plot D.—Exactly as in Plot C but the solution used was one per cent of germisan and 0.2 per cent of yellow soap in water.

Plot E.—Exactly as for Plot B but the solution used was 0.5 per cent of germisan and 0.2 per cent yellow soap in water.

Plot G.—One per cent germisan in methylated spirits stirred for five minutes, squeezed slightly and dried for thirty minutes to their original weight.

Plot F.—Control.

Disease estimations were made throughout the season and Table No. 1 gives the percentage of infected plants in each plot.

TABLE No. 1.

DISEASE ESTIMATIONS : QUALITATIVE EXPERIMENT.

Date.	A.	B.	C.	D.	E.	F.	G.
4th October, 1928 ...	0·6	0·6	—	0·4	—	44	—
30th October, 1928 ...	12·5	9·4	12·6	30·8	2·5	59·3	3·8
22nd November, 1928	15	20·9	14	20·9	1·7	58	4

Note :—The first estimation represents the percentage of plants bearing disease ; the second estimation represents percentage of plants bearing lesions in sufficient numbers to affect the plant appreciably ; the third estimation is of fresh lesions only.

It will be seen from the first estimation that in three of the six treated plots there was no disease whilst in the remainder there was only an insignificant amount. Later, however, as a result of infection by wind and rain the disease was present in all plots but to a greater extent in the control one.

In the quantitative experiment there were five control and four treated plots each of one-fifth acre. The plots were separated by a screen of guinea-corn half a chain wide and there was a screen also one chain wide surrounding the whole of the experimental plot. The treatment was the same as in the qualitative plot G, viz. one per cent germisan in methylated spirits. The following table gives the mean percentage of diseased plants at each assessment for both treated and control plots.

TABLE No. 2.

DISEASE ESTIMATION : QUANTITATIVE EXPERIMENT.

Date.	Treated Plots.	Control Plots.
	%	%
3rd October, 1928	5·3	33·9
30th October, 1928	14·1	47·8
22nd November, 1928	21·0	44·0

Note :—The footnote in the previous table applies to these estimations also.

It will be noted that the treatment did have a considerable effect in reducing the amount of the disease. Unfortunately, conditions were unfavourable for cotton growing generally during this year, and owing to lack of rain not even an average stand was obtained until late in August. Moreover, the site of the quantitative experiment was changed so that the guinea-corn screens had to be transplanted and were inoperative at the critical time during

September. Their value in isolating neighbouring plots of cotton was negligible until later in the season. For these reasons the experiment was not satisfactory.

The investigation, however, appeared to give promise of useful results and it was decided to repeat it during the following season but this time cotton seed treated with one per cent germisan in a 0.2 per cent solution of soap in water was used in the quantitative experiment. It was further decided to increase the width of the guinea-corn screens from half chain to one chain between the plots and a screen one chain wide surrounded the whole of the plots as before. There were fourteen one-tenth acre plots, six treated and eight control arranged alternately and separated by the screen of guinea-corn one chain wide. The seed was planted on July 5th at which time the guinea-corn was, on an average, only one foot high. Estimations of bacterial disease were made during July, September, October and November. The first estimation was made twenty-four days after the cotton was planted. It was carried out at this early date because any disease then apparent would be only such as was purely seed borne. The first figures given in the table below refer, in the first estimation, to diseased stands and not to individual plants. Most of the plants in a stand which showed disease were infected. Not a single stand in the treated plots showed disease at this stage whereas the mean percentage of the controls was twenty-one.

In order to ascertain that the treatment was only external Mr. Watson kindly tested the seeds for the presence internally of the fungicide. The disinfected seeds were heated until the testa became slightly charred and brittle and in this condition by gentle pressure it broke away easily leaving the seed contents which could be removed without touching the testa. Three tests were made for the presence of organic mercury within the seeds and all gave negative results. It would appear from this experiment that the germisan treatment was purely external and yet it did destroy the organisms which were present on the seed. Table No. 3 gives details of the disease estimations throughout the season.

TABLE No. 3.

QUANTITATIVE EXPERIMENT: ESTIMATION OF DISEASE, 1929.

Date.	PERCENTAGE DISEASED PLANTS.						
	Untreated Plot 3A.	Treated Plot 6A.	Untreated Plot 9A.	Treated Plot 12A.	Untreated Plot 15A.	Treated Plot 18A.	Untreated Plot 21A
30th July, 1929 ...	17	—	23	—	22	—	23
11th September, 1929	51	3·4	56	4·5	71	5·4	69
15th October, 1929 ...	97	72·0	98	73·0	99	76·0	100
22nd November, 1929	58	28·0	70	44·0	66	35·0	79

TABLE No. 3—continued.

Date.	Percentage Diseased Plants.						
	Untreated Plot 3.	Treated Plot 6.	Untreated Plot 9.	Treated Plot 12.	Untreated Plot 15.	Treated Plot 18.	Untreated Plot 21.
30th July, 1929 ...	22	—	18	—	25	—	18
11th September, 1929	58	1·5	57	4·0	59	6·8	57
15th October, 1929 ...	98	68·0	99	65·0	99	64·0	100
22nd November, 1929	63	27·0	82	40·0	71	48·0	64

It will be noted that there was a very great increase in the amount of disease in October and one important factor to account for this is that, between the time of the September and the October assessments of disease, there was as much as 16.27 inches of rain.

Throughout the season the screens were not effective. They made poor growth and eventually the disease was general throughout all the plots.

The qualitative experiments were also carried out on isolated one-tenth acre plots surrounded by high grass and as will be seen from Table No. 4 below the seed-borne disease was controlled in all treated plots with the single exception of the sulphuric acid plot.

TABLE No. 4.

Qualitative Experiment: Estimation of Disease, 1929.

Plot.	Treatment.	Date of Examination of Plots and % deceased plants.			
		31st July, 1929.	11th Sept., 1929.	15th Oct., 1929.	22nd Nov., 1929.
A.	Sulphuric Acid	1	2·0	80	15·0
B.	1% Germisan and 0·2% soap solution ...	Nil	Nil	20	10·0
C.	1% Germisan injected ...	Nil	Nil	9	3·8
D.	1% Germisan and 0·2% soap solution injected	Nil	0·8	24	11·0
E.	0·5% Germisan and 0·2% soap solution	Nil	0·2	5	6·4
F.	Control	47	41·0	98	12·8
G.	1% Germisan in Methylated spirit	Nil	Nil	10	9·0
H.	Control	43	45	97	16·5

As in the experiments of the 1928-29 season the yields during the following season did not show any significant results and the soil

conditions in both plots used for the experiment were poor and such that it was extremely doubtful whether any economic return from cotton cultivation could ever be obtained.

In the season 1931-32 it was decided to repeat the quantitative experiment on a plot of land reported to be of good quality. Every effort was made to make a screen which would be efficient and, for this purpose, it was decided to plant early maize and follow this by guinea-corn. Also, the land for the screens was ridged in one-half along the length of the screen and in the other across its short side. The block of land available was small and consequently the plots of cotton were only three-fortieths of an acre. There were six controls and five treated plots alternating and separated by the screen of early maize and guinea-corn. The maize was providing a good screen at the time of planting of the cotton on July 9th but the guinea-corn had been damaged by locusts and was only from three to nine inches high. However, the screen throughout the season was much superior to those obtained in the previous experiments. Assessments of disease were made in August, September, October and November and the mean percentages of disease are shown below.

TABLE No. 5.

PERCENTAGES OF DISEASED PLANTS: QUANTITATIVE EXPERIMENT 1931-32.

Date.	C.	T.	C.	T.	C.	T.	C.	T.	C.	T.	C.
19th August, 1931 ...	16	—	16	—	20	—	17	—	18	0·5	15
23rd Sept., 1931 ...	26	1·2	17	—	15	—	15	—	8	—	14
21st Oct., 1931 ...	76	2·0	61	5	60	11	76	3	62	12	74
25th Nov., 1931 ...	75	5·0	72	5	80	13	84	5	66	9	81

C = Control. T = Treated.

It will be seen that practically complete control of the disease was obtained in the early stages of the developing cotton plants and at no time throughout the experiment was it very prevalent on the treated plots. The difference between the plants on the controls and those on treated plots was very marked in November. As a result of angular leaf spot there had been considerable defoliation of the untreated plants whereas those from treated seed still had a large healthy leaf development. The efficacy of the treatment, whilst thus apparent throughout the growth of the cotton plants, is strikingly shown when we consider the yields from all plots. Table No. 6 shows in every case an increase in yield on the treated plots as compared with the mean of the adjacent control plots.

These increased yields are so great that one is justified in regarding them as evidence that external disinfection of cotton seed, by checking the development of bacterial diseases, is an economic and practical measure.

The results show quite conclusively that bacterial disease can be very thoroughly controlled by external disinfection of cotton seed. The treatment is a simple one and quite inexpensive. The addition of soap to the solution reduced the surface tension of the liquid to about one-half and enabled the fluid to penetrate more rapidly within the fuzz hairs. The treatment has very little adverse effect on the germinating capacity of the seed.

TABLE No. 6.

DISINFECTION OF COTTON SEED EXPERIMENT AT ILORIN, 1932.
QUANTITATIVE EXPERIMENT.

Plot.	Yield per acre lb.	Increase or Decrease over mean of adjacent controls lb. per acre.
1. Control	156	—
2. Treated	351	+175
3. Control	195·8	—
4. Treated	348·7	+138
5. Control	225	—
6. Treated	197·5	+ 6
7. Control	157·5	—
8. Treated	230·4	+ 74
9. Control	156	—
10. Treated	173·3	+ 43
11. Control	102·3	—

Average yield of control plots = 165·4 lb. per acre.

Root mean-square difference between adjacent controls = 44·1 lb. per acre.

Standard Error = 19·8 lb. per acre.

Average difference in treated plots = + 87 ± 19·8 lb. per acre.

There is one point which requires elucidating and which is of practical importance. It has been assumed that treatment of the seed should be carried out just prior to planting because it was thought that if treated and left for a time the seed might possibly become reinfected. Now it would obviously be a much more practical measure if large quantities of seed could all be treated some time prior to planting and then distributed by officers in charge of extension work. Also, if such seed could be utilised for subsequent supplying it would be an advantage. A useful experiment in the future would be to treat a quantity of seed and

plant it at various dates after treatment at intervals of one week. Thus treated seed kept for 1, 2, 3, and 4 weeks or longer could be planted and the seedlings examined for signs of the disease. The examination need not be extended beyond the seedling stage as this would indicate sufficiently whether the seed had become reinfected.

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(*Received for publication on 4/6/32.*)

IMMATURITY IN NORTHERN NIGERIAN COTTON.

By J. K. Mayo, M.A.

Several varieties of cotton were introduced to the Northern Provinces in 1912 with a view to displacing the indigenous *G. peruvianum* (Gwundi-Hausa). These were grown on the Government plantation at Maigana and in 1915 sample bales were sent to England for a Brokers Report, and were described as follows :—

Variety.	Value.	Classification.
"Gwundi" ...	100 on...	... About middling grade. Staple one one-eighth inches strong.
"Allen" ...	130 on...	... About middling fair grade. Staple one three-sixteenth inches rather neppy (soft) fairly strong.
"Nyasaland"	100 @ 120 on	Very good colour. Middling fair grade. Staple full one one-eighth inches strong.
"Georgia" ...	80 @ 90 on ...	Fully good middling grade, staple one one-sixteenth inches fairly strong.

It is particularly interesting to note that the Brokers added the following caution : " On the whole the Nyasaland is the best result. The Allen, as is so often the case, is a little bit inclined to be soft and we think that this type of cotton is not really a satisfactory one to grow unless you have perfect conditions ".

Allen, however, was multiplied and was taken up enthusiastically by the farmers, and the indigenous variety disappeared. The cotton appealed to the farmers chiefly because at that time they were offered 1¾d. for Allen as opposed to 1d. for Gwundi, but also because it appeared to yield better, and certainly came to maturity earlier.

It is probable that natural crossing took place at Maigana between Allen and the other types grown there, and that the latter have contributed to the present-day Allen stock.

The success of Allen reached a peak in 1925 with 37,000 bales. The following season complaints began to be made in Lancashire about the neppiness of Allen cotton. Many explanations were offered to account for this, such as inferior grading, unfavourable season (the rainfall was below normal in September and October), bad ginning, inferior seed and the like. In 1927 samples were sent to the British Cotton Industry Research Association who reported as follows :—

" An examination of the seed cotton showed the presence of—

(1) immature seeds

(2) seeds apparently unfertilised and with only a growth of short dead cotton and

(3) a proportion of immature cotton in bulk of normal seeds.

The sufficient cause of all the trouble is this immature lint. Ginning dry and dense packing may aggravate the trouble but their effects cannot be seen. This is a familiar fault in Northern Nigerian Allen, and seems to be characteristic, not caused by unseasonable picking ".

The actual figures for immaturity were given as follows : —

	% Normal.	% Thin Walled.	% Dead.
Allen 1926 crop	57	22	21
do. dirty cotton picked out from above	48	20	32
Memphis (for comparison)	72	17	11

It was therefore concluded that better grading could have little effect, and that the cause of the trouble was to be sought in the peculiar climate and/or the variety. Accordingly a number of other varieties were ordered from abroad, and an experiment was drawn up to investigate the effect of certain environmental factors on the cotton.

Nep. Experiment 1927.

In view of the peculiar climate (*see* table appended), which changes from very wet in September to very dry in November, it was decided to try the effect of watering some cotton plants and root-pruning others to aggravate the drought effects. Again, since the failure to produce normal thickening of the hairs pointed to carbohydrate deficiency, defoliation was tried.

On the 5th November, when the first boll opened, fifty groups, each of four similar plants, were chosen at random in an acre of Allen cotton. Within each group one plant was watered, another partially root-pruned, another defoliated, and the fourth left as a control. The intention in root-pruning was to cut the tap-root six inches below the surface and leave the plant to carry on with such laterals as came off above it. In practice this was found to be very difficult because at about four inches below the surface the tap-root had generally been deflected, and in many cases it had divided into several roots of equal size. This was ascribed to waterlogging in September. The watering treatment was four and a half pints (1 Winchester bottle) every second day.

The bolls as they ripened were harvested separately (cut off with a knife) every three days and examined in the laboratory. It is possible to estimate roughly the amount of immature fibre present

in a boll, if the lint has not been touched or exposed too long to the weather, by the silvery appearance of the individual locks. This was done. At the same time the locks were examined for dead seeds.

Owing to the labour involved in measuring immaturity, samples of only four separate pickings were chosen for submission to the Shirley Institute. The following table shows the results alongside the figures for dead seeds worked out at Samaru.

N.B.—The maturation period of the boll in Allen here is fifty-three days.

Date picked.	Treatment.	Seed harvested.	Percentage Dead seeds.	Percentage Dead hairs.	Percentage Normal hairs.
26.11.27 20 days after treatment	Watered ...	91	3·3	6	73
	Root-pruned	204	1·5	12	54
	Defoliated...	227	·44	14	42
	Control ...	229	·87	11	62
14.12.27 38 days after treatment	Watered ...	327	2·45	10	60
	Root-pruned	705	4·40	13	59
	Defoliated...	269	27·90	49	19
	Control ...	727	·96	9	57
29.12.27 53 days after treatment	Watered ..	951	2·95	3	77
	Root-pruned	337	6·83	13	66
	Defoliated...	120	40·90	4	81
	Control ...	659	2·73	8	62
4th, 8th and 11th Jan., 1928. 63 days after treatment.	Watered ...	950	4·80	10	66
	Root-pruned	399	5·80	12	74
(3 last pickings bulked).	Defoliated...	153	28·90	15	77
	Control ...	552	3·3	.7	62

	Total Yield (number of seeds) harvested from different treatments.	Percentage differences from control.
Control	8,469	—
Watered	7,763	− 8%
Root-pruned	6,951	−18%
Defoliated	4,300	−49%

The figures for proportion of normal hairs in this experiment are more in accordance with expectation than those for dead hairs. Thus the watered plants, though not showing the improvement expected, have more normal hairs than standard throughout the experiment, but their proportion of dead hairs varies inexplicably, and both root-pruned and defoliated showed a low proportion of normal hairs twenty days after treatment, but no serious increase in the proportion of dead hairs on that date.

It is obvious that defoliation must increase immaturity but it was thought that quantitative details were worth obtaining. The strength of the recovery fifty-three days after treatment is remarkable. It is clear from the table that the proportion of dead seeds in cotton is no indication of the proportion of immature lint. for the " defoliated " sample picked on the 29th December contained forty per cent dead seeds while the lint was exceptionally free from immaturity. This is supported by the notes on silveriness and weakness of the lint (excluded from this paper as no numerical value could be given them). It was noted that on the 26th December " ' defoliated ' seems now to be getting stronger ", and on the 29th December " ' Drag ' of ' defoliated ' appears to have recovered ". This was attributed to a slight growth of new foliage which developed after the original defoliation. There is no obvious change in immaturity of the controls during the experiment, so that if the normal environment is to be blamed it must take effect earlier than in November. Possibly the watering should have begun in early October before the harmattan.

It is well known that lint length has often been increased by manuring, and the suggestion has been made that immaturity might be reduced by the same treatment. The figures for two strains grown on good and bad land in 1931 lend some support to this theory :—

Strain.	% Normal Hairs.		% Dead Hairs.	
	Good land.	Poor land.	Good land.	Poor land.
L	35	32	9	13
C	23	27	9	21

The good land yielded 670 lb. seed cotton per acre. The poor land yielded 112 lb. seed cotton per acre. Part of the difference in yield is probably due to better cultivation and a more perfect stand on the good land.

Selection.

Pure line selection with the aim of improving the staple of Allen, was begun in 1924 when that variety was still sufficiently impure to allow of selection. In 1928, in view of the small amount of progress achieved and the complaints of nep in the general crop, several other varieties were introduced. A summary of the results of these trials is given below. (*See* also Table A appended).

Variety.	Source.	Remarks.
Mesowhite ...	Iraq ...	More immature than Allen and inferior in yield.
Acala ...	U.S.A. ...	Succumbed to jassids.
F285, F289 ...	India ...	Inferior in yield and quality.
A12, U4, Z1 ...	S. Africa ...	Equal in yield but inferior in quality.
H21 ...	U.S.A. ...	Inferior in yield but superior to Allen in quality (Brokers found no "nep" but Shirley Institute figures do not support this).
Co. 1, Co. 2 ...	India ...	Equal in yield but inferior in quality.
S.G. 27, S.G. 29 ...	Uganda ...	Introduced in 1931 and not tested yet.
Ishan ...	S. Nigeria ...	Superior quality but very poor yield.

Continued selection in Allen has however produced a strain ("L") which appears to be superior on the whole to any other cotton so far tried here. It is equal in yield and ginning percentage to the parent stock and is superior in quality except on the worst land. Immaturity figures for the last three seasons (Table A appended) show that L is superior in so far as it has a low proportion of dead hairs. It will be noted that there is a tendency for the proportion of thin walled hairs to increase in these reports at the expense of the normal hairs. No explanation of this can be offered unless it be that the standard has been raised at the Shirley Institute.

Conclusions.

In the experiment described, the controls did not become more immature with time, and the watered plants were on the whole similar to the controls. It may be concluded therefore that

Note.—Strain L has subsequently been discarded owing to susceptibility to disease.

immaturity is not caused by the dry conditions in November and December. It is possible however that the climate is an indirect cause of the trouble, through its influence on the choice of variety. The varieties which yield well in this district have been found to be those which can be planted late enough to escape pests and yet set a large crop before the aridity in November and December slows down plant growth. Late planting has another advantage in that it fits in with local farming practice. Such a cotton, producing a relatively large number of bolls in a short time, is more likely to produce immature lint (through competition of bolls for carbohydrates) than is a cotton with a longer growth period, such as Ishan. The introduced varieties which have yielded well under these conditions suffer from immaturity in the same way as Allen and are indeed of the same type. It is possible that the Ishan would have produced lint free from immaturity in Zaria but, owing to its poor yield, it never reached the stage of being tested for this defect.

It seems, therefore, that any cotton which yields as well as, or better than, Allen will always be liable to produce immature lint. Any strain or variety giving a lower yield, which is intended to replace Allen, must at least command a premium for quality large enough to compensate for the loss of yield : for Allen, in spite of its defects, still finds a ready sale.

Acknowledgments.

The author is indebted to Mr. A. G. Hill (late of this Department) for co-operation in the experimental work, and to the Shirley Institute, Manchester, who are responsible for all the immaturity figures.

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TABLE "A".

THE RESULTS OF TESTS CARRIED OUT BY THE SHIRLEY INSTITUTE, MANCHESTER.

Season.	Variety.	% Normal.	% Thin Walled.	% Deed.
1930 ...	"L" ...	49	32	19
	"Allen" ...	39	31	30
	H21 bulk ...	35	35	30
	A12 " ...	25	32	43
	F285 ...	39	34	27
	Mesowhite	26	33	41
	Grown under strictly comparable conditions in a yield trial.			
	Argentine (control sample supplied by Shirley Institute for comparison) ...	62	29	9
1931 ...	"L" ...	44	49	7
	"Allen" ...	39	43	18
	"C" ...	41	51	8
	H21-3 ...	54	27	19
	A12 seln. ...	46	30	24
	U4 seln. ...	42	31	27
	Grown under strictly comparable conditions in adjacent yield trials			
	Memphis ... S. I. (U.S.A.) (growth) ...	45	39	16
	Mississipi Controls	62	30	8
1932 ...	"L"	35	56	9
	"Allen"	30	52	18
	"C"	23	68	9
	U4	24	60	16

Note.—"C" is another selection from Allen.
"H21-3" is a selection from H21. Discarded owing to inferior yield.

ZARIA CLIMATE.

The rainfall in Zaria township from 1904 to 1931 was as follows:—

Month.	Average rainfall.	Highest figure for the month.	Lowest figure for the month.	Highest (1906) whole year.	Lowest (1907) whole year
January	·002 ins.	·04	nil (26 times)	nil	nil
February	·018 "	·36	nil (23 times)	nil	nil
March	·31 "	3·57	nil	nil	nil
April	1·75 "	5·20	nil (in 1904 only)	·85	2·20
May	4·61 "	9·50	1·91	9·50	3·69
June	6·46 "	10·33	2·37	5·95	7·05
July	9·25 "	15·11	3·75	14·49	3·75
August	12·35 "	20·93	4·46	16·39	4·46
September	8·48 "	17·46	3·63	9·90	6·35
October	1·48 "	4·36	nil	3·95	2·32
November	·024 "	·44	nil	·04	nil
December	nil	nil	nil	nil	nil
	44·75			61·05	29·82

Other details for temperature evaporation and relative humidity are available for three years (1929-1931) and are as follows :—

AVERAGE OF METEOROLOGICAL DATA AT SAMARU 1929-1931.

Month.	Rainfall.	Daily Evaporation.	2 P.M. Relative Humidity.	TEMPERATURE.	
				Average Maximum.	Average Minimum.
January	nil	92·3 ccs.	16·3	90·1	55·8
February	nil	111·5 „	13·6	94·6	62·1
March	·17	111·5 „	16·0	101·1	65·9
April	1·29	75·3 „	31·3	99·7	70·3
May	5·76	42·7 „	49·3	93·7	70·1
June	5·87	26·9 „	58·0	88·2	67·1
July	10·10	21·4 „	65·0	84·7	66·8
August	12·85	18·0 „	67·6	84·1	66·1
September	9·09	18·9 „	63·0	86·5	66·5
October	·92	36·6 „	45·3	89·8	64·8
November	·02	69·6 „	24·0	92·8	60·7
December	nil	88·0 „	15·3	91·4	56·1
	46·07				
Highest single reading ...	3·66	173·0	97	107·5	75
Lowest single reading ...	·01	1·7	2	70·0	49

The evaporation is that given by Livingston white spherical atmometers with the actual number of ccs. lost multiplied by the constant .81. The atmometers are porous spheres 5 cm. diameter with a neck for the water supply. They were exposed to the weather on a pillar fifteen feet above the ground. The thermometers were housed in a small thatched shelter seven feet high and mounted two feet below the thatch. The thermometer bulbs were level with the edge of the thatch. They were read at 7 a.m. and 2 p.m. (Nigerian time).

The figures for relative humidity were worked out from "Tables of the reduction of Meteorological Observations" published by the Government of India in 1910. The lowest figure recorded was on March 22nd, 1930, when there was a strong harmattan blowing. The thermometers stood as follows :—

Dry bulb.	*Wet bulb.*	*Diffce.*	*R.H.*
99.4°F	61.5°F	37.9°	2

Relative humidities as low as five are reached on several occasions every year.

(Received for publication on 5/11/32.)

A STUDY OF CONTROLLED POLLINATION IN CACAO (*Theobroma cacao*).

By O. J. Voelcker, M.A.

A programme of selection work on cacao at Moor Plantation, Ibadan, was commenced early in 1931, but it was realised that a full season would have to elapse before the discovery of suitable trees from which to breed. In the meantime the delay afforded an opportunity to investigate methods of pollination and such factors as seasonal variation, weather conditions and time of day, any of which might influence the success of fertilization. Although an interesting account of the history of fruit after setting has been given by Hewison and Ababio (1), the accumulation of further figures was thought desirable, especially such as might bear on the vexed question of pod shedding. With this in view, a record was kept of the behaviour of all flowers after being pollinated by hand.

Design and Routine.

Six trees were selected from a block of yellow Forastero amelonado cacao planted 15′ × 15′ in 1912. These trees were in good health, were flowering freely, and had suitable trunks or lower branches on which to attempt controlled pollinations. All the figures given hereafter relate to the six trees taken as a whole.

The method of controlled pollination, which entails the use of match box covers, has been explained in a previous paper (2) and was employed throughout the whole experiment. Flowers were first pollinated on the 24th of March, 1931, and thereafter every day (except when all six trees were without buds) until the 23rd of March, 1932. As far as possible, all flowers which could be enclosed by the boxes were pollinated: though at the peak periods of flowering, it was found impracticable to have more than about ten boxes on any one tree. Flowers that were naturally fertilized were not removed except where they interfered with the controlled pollinations. With the exception of very cool mornings, when the work was postponed several hours, pollinations were made between 8.30 a.m. and 9.15 a.m.

Records were kept in the following manner:—

Each box which enclosed a bud was numbered, and the number of the box, together with the tree number acted as the distinguishing mark for the flower up to the fourth or fifth day after

pollination; thereafter the box was removed, and a label, showing the date of pollination, pinned to the bark immediately adjoining the young fruit stalk. Each morning every box was inspected, and any pollinated flowers that had fallen were recorded. By this means, the exact number of days interval could be given between the time of pollination and the falling of any flower or fruit. It may be mentioned here that the first signs of yellowing in young fruit were taken as the date of falling. Weather conditions were noted daily.

Presentation of Data.

Taken over the whole year 532 flowers were pollinated, and of these, 141 or 26.4 per cent were harvested as mature fruit. This can be considered satisfactory, and the method appears applicable for experimental breeding or for the initial stages of selected seed production. Figures are now given in fuller detail.

Pollination Dates for Production of Mature Fruit.

Pollinations carried out at all times of the year, with the exception of dates covering roughly the months of August (1 fruit), September, October, November led to mature fruit; but as might be expected, most fruits were obtained from those pollinated during the early rains which coincide with the greatest production of flowers. In fact, only eight flowers were found suitable for pollination during the months mentioned above. Table I shows the number of flowers pollinated (column 1) and the resulting number of pods which reached maturity (column 4).

Intervals of twenty-eight days were chosen for convenience. The number of flowers pollinated gives an indication of the relative state of flowering on the trees, though the scarcity of flowers in May, followed by a heavy flush in June, is somewhat masked. Percentages of pollinations to fruits reaching maturity for each twenty-eight day interval have not been given, as a wrong impression might be gained where the numbers are small. At the same time the figures for December - twenty-five flowers pollinated yielding ten ripe pods—is somewhat unexpected, more especially as January was characterised by very strong *harmattan*, a climatic condition brought about by prevailing northerly winds which reduce considerably the relative humidity and temperature. The flowering periods covered by the months of April, May and June are shown to be most suitable, and it is probable that even greater success could be obtained if all naturally fertilized pods were removed. Actually, during the same period of harvesting (28/8/31 to 22/8/32), no fewer than 1,055 naturally fertilized pods were gathered from the six trees

TABLE 1.

YIELDS FROM CONTROLLED POLLINATED CACAO FLOWERS.

28 Day Intervals.	1 No. of Flowers pollinated.	2 No. of Flowers fallen before 4th Day.	3 No. of Flowers fertilized but fallen later.	4 No. of Mature Fruit harvested.
March 24, 1931 to April 20	97	22	69	6
April 21 to May 18 ...	83	7	38	38
May 19 to June 15 ...	61	15	16	30
June 16 to July 13 ...	74	7	43	24
July 14 to August 10 ...	56	2	47	7
August 11 to September 7	26	2	24	0
September 8 to October 5	1	0	1	0
October 6 to November 2	2	0	2	0
November 3 to November 30	1	0	1	0
December 1 to December 28	25	2	13	10
December 29 to January 25, 1932	33	5	22	6
January 26 to February 22	21	3	15	3
February 23 to March 23 (30 days)	52	9	26	17
Total	532	74	317	141
Percentage ...	100	14·0	59·6	26·4
			86·0	

Pollination Dates for Successful Fertilization.

Column 2 of Table 1 shows the number of flowers which fall before the 4th day; these were considered not to have been fertilized. Stahel (3), in a comprehensive study of the biology of the cacao flower, states that " the flowers that have not been fertilized drop off on the second or third day ", and Jones (4), writing on the same subject, mentions that " ..... if fertilization is not effected during

this time the flower drops off early the third day ". The rather high figures of failures for the periods 24th March to 20th April, and 19th May to 15th June were due, in the former, to the writer's lack of experience in the method of pollination, and the latter, to that of the assistant who took over the work in his absence. Making allowance for these two periods, it will be noted that fertilization took place readily any time of the year, even during the *harmattan*. It was the shedding after fertilization which determined mainly the number of mature pods obtained from pollinated flowers.

Controls.

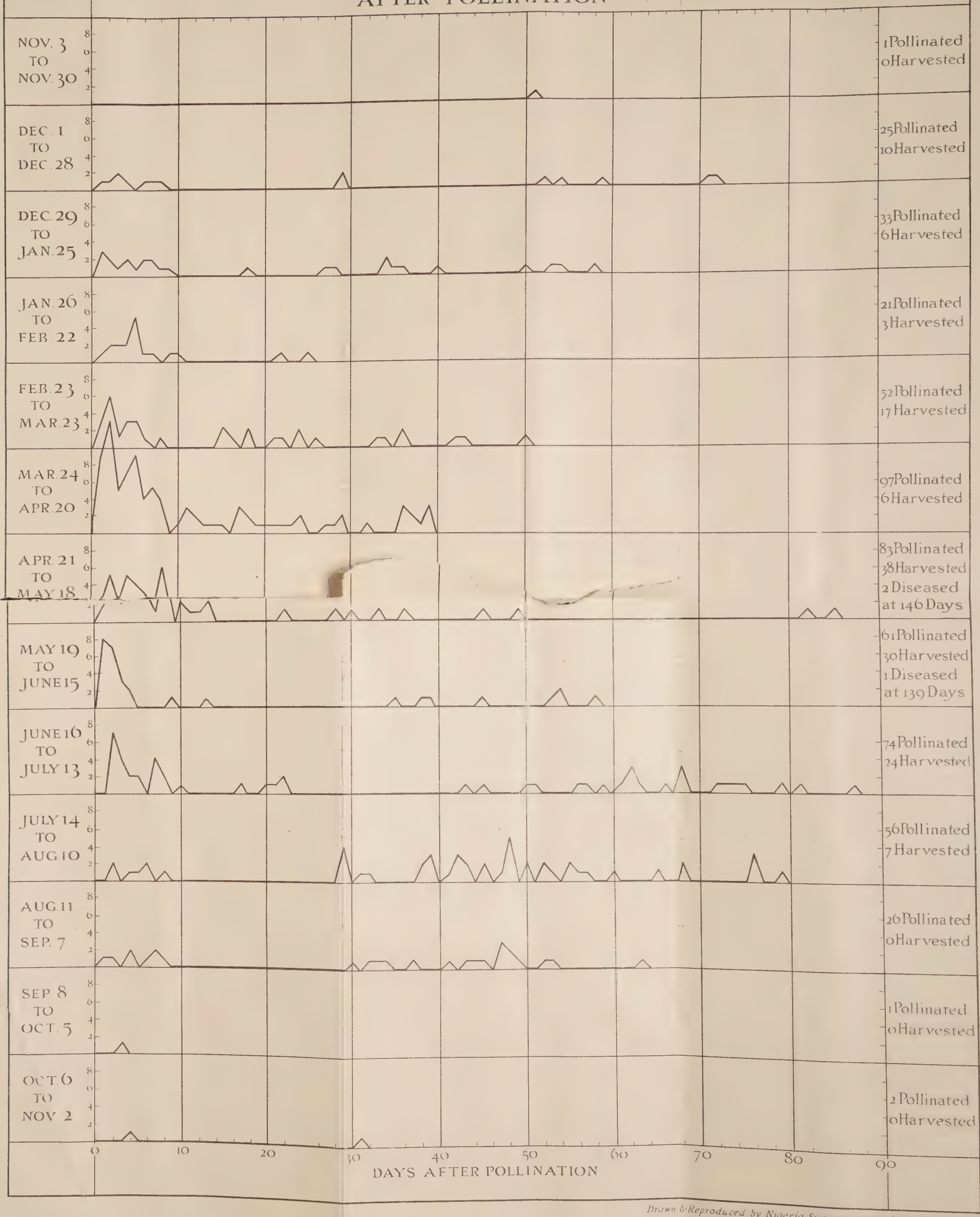
Whenever there was a plentiful supply of buds several were from time to time enclosed in boxes, but were not pollinated. In all 101 buds were so treated. Of these, forty-four fell on the second day after opening, fifty-two after the third, four after the fourth and one after the fifth; this last was attacked by a fungus. It may be mentioned here that fertilized flowers and flowers in their first day after opening can withstand a considerable amount of rough treatment, while after the first day, those not fertilized will fall at the slightest touch. It seems that the numerous flowers found lying on the ground after tornadoes are only those which have been open for two or three days, but not fertilized. The wind and rain merely hastens the inevitable fall of such flowers.

Fruit Shedding.

Heavy shedding took place during the first eight days after fertilization at all seasons of the year. After the eighth day the season played an important part in the development of the young fruit. Two distinct periods were apparent; the first is covered roughly by the months of January, February, March, April; the second by May, June, July, August. Flowers fertilized during the first period were shed continuously up to the fiftieth day; but almost all those remaining at that date eventually matured. In the second period there was a distinct cessation of shedding which lasted with rather surprising regularity for nineteen or twenty days, and occurred after the eighth to sixteenth day from pollination; no shedding occurred during the nineteen or twenty days, but after that it became very pronounced, and lasted up to the eightieth day. The accompanying graph shows this clearly. Figures of pod shedding given by Hewison and Ababio (lit. cit.), taken over the whole year, tend to mask the change in behaviour of flowers fertilized at these different periods. They remark that there is a heavy shedding (up to thirty per cent of young fruit) within the first week after setting, followed by a comparatively quiescent period during the

CACAO

SHEDDING OF FLOWERS AND FRUIT AFTER POLLINATION



Drawn & Reproduced by Nigeria Surveys, Lagos, June, 1934.

second and third weeks, which terminates in renewed losses from the fourth to seventh week. Losses then become progressively less. Turning now to the graph, it will be seen that from 26th January to 18th May there were only two losses after the fiftieth day, whereas from the 19th May to 7th September there were no fewer than forty-two. Similarly there were forty-two losses between the 10th and 30th day in the first period, and only ten such losses in the second. Shedding within the second period lasts up to eighty-seven days from pollination in the interval 16th June to 13th July. During the other three intervals of this second period shedding ceases at an earlier age of the young pods.

Discussion of Results.

The figures obtained for successful pollinations over the whole year compare favourably with those of Stahel who employed a different method. He found that about eighty per cent of pollinated flowers set fruit, and this figure is similar to the 86.0 per cent recorded here. When it is remembered that no more than .5 to 2.5 per cent (Hewison and Ababio, lit. cit.) of flowers under natural conditions are fertilized, it seems certain that the cause of this low figure is the lack of adequate pollinating agencies. The heavy shedding of fruits after either natural or artificial fertilization suggests that probably no increased yield of mature pods can be obtained by artificial means.

There is a wide range of dates on which pollinations can be made with the prospect of obtaining mature fruit, and it is probable that the range could be extended if natural fruiting were not permitted. Climatic conditions at the time of pollination seem to have no effect on the success or otherwise of fertilization, except in so far as low temperature may delay the time at which the anthers open. The anthers, which normally open shortly before sunrise, lose their pollen rapidly: thus artificial pollination must be carried out early in the morning.

Shedding of young fruits is generally considered to be bound up with the occurrence of vegetative flushes which take place from time to time throughout the year (Stahel); while this may be true in cases of shedding where the pods are several weeks old, it does not explain the loss of pods during the first week after fertilization, nor does it explain the remarkable "twenty day safety zone" previously described. It is probable that there are physiological causes of shedding other than those which determine the incidence of vegetative growth.

Summary of Results.

1. Controlled pollinations carried out over one year yielded 86.0 per cent fertilized fruits and 26.4 per cent mature pods.

2. For the maximum production of mature pods pollinations were between April 21st, and July 13th.

3. No mature pods were obtained from pollinations made between August 11th, and November 30th.

4. Pollination must take place within a few hours of sunrise except on cold mornings.

5. Weather conditions at the time of pollination did not effect the success of fertilization.

6. At all seasons of the year shedding was heavy for about eight days after fertilization.

7. During the period January 26th to May 18th, shedding was continuous amongst pods of less than fifty days old after pollination; fruits that reached that age eventually matured.

8. During the period May 19th to September 7th, an interval characterised by no losses was noted; this was followed by renewed shedding up to about the eightieth day.

Acknowledgment.

The writer wishes gratefully to acknowledge the assistance given by Mr. E. J. Spiff, who helped him throughout most of the year and took over the work during his absence.

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INITIAL CACAO SELECTION IN NIGERIA.

By O. J. Voelcker, m.a.

Perhaps the most characteristic botanical feature of Nigerian cacao, both as regards the tree and the beans, is uniformity. Methods of preparation may give one district a better name in the trade than another, but the somewhat flattened purple bean contained in the typically shaped yellow Amelonado pod is, with very few exceptions, the hall mark of Nigerian cacao. In the Cameroons, the European estate owners grow a variety having a much larger pod, generally some shade of red or purple when unripe, and a fuller bean. This variety is also common among the native plantations in that neighbourhood. A few of these red pod types are also to be found in the Agege district, where, in the early days of cacao cultivation, seed from red pod trees grown at Ebute Metta Botanical Gardens and at the government's model farm at Agege was distributed. It is most uncommon to find other than the yellow Amelonado pod type growing in the Ibadan, Ife, Ilesha or Ondo districts which together produce the bulk of Nigerian cacao.

Material Available.

Work on cacao selection was commenced in 1931, and a description of the available material is now given.

Moor Plantation, Ibadan.—Two plots of cacao had been established in 1912, and since 1921 individual tree yields in pods had been kept. One plot of 2.5 acres had been planted with yellow pod Amelonado, the other of 4.75 acres with a red pod variety. The planting distance in each plot was divided between twelve and fifteen feet square. Rain tree (*Pithecolobium saman*, Benth.), shade was established through both plots but was cut out in yellow pod plot in 1926. Shade was also removed at that time from the red pod plot with the exception of about one acre.

Eleven small isolated plots, which in 1931 each contained from one to fourteen trees had been planted in 1914, 15 and 17. Each plot was established with the progeny of a single tree, but unfortunately there is some doubt of the precise identification of the plots since little attention was subsequently paid to them. The seed had been obtained from several sources, namely from the Gold Coast,

the Cameroons, Agege and from local farms. Further notes on these plots are given later in this paper.

Agege.—Sixteen acres were planted with cacao in 1910 as a spacing trial. Owing to the very uneven stand and to the increasing number of deaths, no significant result could be obtained. Individual tree yields were not available, and it was decided in 1931 to abandon the area to other crops.

Benin and Umuahia.—Cacao planted at these stations in 1925 has not thrived, and indeed, can scarcely said to have been established.

The Cameroons.—Both in the Botanic Gardens, Victoria, and in the European plantations selection might bring to light valuable types. The overwhelming difficulty of distance however, precludes work in this area at present.

Preliminary selection was therefore inevitably confined to those trees growing on Moor Plantation. The individual tree yields over eleven seasons were of the utmost value, and situated as these trees were at headquarters, the facility with which investigations could be conducted on matters affecting the size and shape of beans and general behaviour of the trees was a factor of great importance. Moreover, any propagation of selected trees could more easily be carried out at Ibadan than anywhere else. The Moor Plantation population is small, and a criticism may be levied that no attention has been paid to the vast number of trees growing on native farms. Since, however, an examination of the past yields of the Moor Plantation trees disclosed promising individuals, it was thought more expedient to concentrate on these rather than to dissipate a limited staff's activities over a wide area in a search for superior high yielding trees on native farms, which would of necessity take several years.

Cacao Yields.

West African cacao has built up its strong position on yield per acre, which, even allowing for the very close planting distances usually adopted, is based on the potential yield per tree. Since yield has been made the criterion on which this preliminary selection was based, it is of interest to give such figures as are available relating to this factor. Table I gives the weight of dry beans per acre from the yellow and red pod plots at Moor Plantation since 1926, (1) but it should be borne in mind that the soil in both plots is poor, especially that of the red pod plot, and that there are thirty-one per cent of the stands vacant in both the plots.

TABLE I.

Season.	Number of stands originally planted = 620. Yellow Pod. 2.5 acres. Pounds of dry beans per acre.	Number of stands originally planted = 1,137. Red Pod. 4.75 acres. Pounds of dry beans per acre.
1926-27	622	103
1927-28	479	164
1928-29	508	222
1929-30	914	370
1930-31	1,251	446
1931-32	1,102	496
1932-33	774	339
1933-34	846	475
Planted 1912.	Average 812.	Average 327.

From the little exact information available on yields from native farms, it seems that even the yellow pod plot falls rather below the average. Thus Mr. West, working on disease control on native farms at Ajia twelve miles from Ibadan, found an average of 900 lb. of dry cacao over the three past seasons. This average was obtained from 3.7 acres divided among plots on several farms; the trees are about eighteen years old. Mr. Trotman in his investigations on cacao thinning in Ondo Province, obtained a yield of 963 lb. of dry cacao over the 1932/33 season. The total area at Ondo was only .7 acre and the trees are about eight years old. Allowing for the actual density per acre, the yellow pod trees at Moor Plantation are not judged to be inferior to those on native farms.

INITIAL SELECTION.

Records show that the Moor Plantation plots were established with seed from Agege, but beyond that no information is available. An examination of the trees in the yellow pod plot, with regard to pod type, shows that there is more variation than is to be found amongst trees growing in native farms. Thus seventeen trees have red or purple pods, five have the long, very warty type associated with the Criollo varieties, and a number are "off type" when compared with the common Amelonado Forastero. Similarly, the trees in the red pod plot show a considerable range of pod forms and colours, the most obvious of which are 164 yellow pod types.

Individual tree yields on both plots have been recorded in number of pods. After analysing these yields it was found that a convenient population, on which detailed investigations could be carried out, would be obtained if all the trees which failed to reach

an average of seventy pods over ten seasons—1921/22 to 1930/31—or failed to reach an average of ninety pods over five seasons—1925/26 to 1930/31—were discarded. This left forty-nine trees from the yellow pod plot and three from the red. Thus it will be seen that the initial selection was based on yield alone.

It was realised that selection for quality, which in this paper means the light coloured bean, though at the moment only taking a secondary place, would later receive attention. Now, when the distribution of selected seed on a large scale becomes feasible, it is hoped that the colour of the pod may be made to designate the type of bean within. Thus a yellow pod would denote a high yielding tree producing purple beans while a red pod would be the external characteristic of those selections which contain " quality " beans. Were this possible the advantage would be enormous. The preliminary selection was confined to the high yielding yellow pod types, and the three red pod trees were therefore discarded. It so happens that both the " quality " introductions from Trinidad and certain trees with light coloured beans growing in the isolated plots mentioned earlier, are associated with reddish pods.

In April, 1931, observations were commenced on these forty-nine yellow pod trees and on those growing in the isolated plots. Harvesting was carried out every three weeks, and at each harvest the number of pods, weight of pods and weight of wet beans were recorded. At what was judged to be the time of the maximum delivery of the crop for each tree the wet beans were fermented in a muslin bag amongst other wet cacao, dried and counted. In this way the number of beans per pod and the number of dry beans per pound were ascertained. It must be remembered that these last two figures only applied to a single harvest, but that in most instances they were obtained from a sample of over thirty pods which recent work in Trinidad (2) has shown to be an adequate number from which to obtain significant results. At the same harvest, rough measurements were made on the length and diameter of the pods. No great accuracy was attempted, and the object was merely to obtain a comparative figure for size of pod from each tree.

The main season for all these trees ceased at the end of January, 1932. It was found that the ratio of number of pods to pod weight and wet bean weight varied within considerable limits, both pod, and wet bean per pod, weights falling with the advance of the season. In reducing the figure of the number of pods to the weight of wet beans, data obtained from the " out of season " crop were discarded. Previous yields which were given in pods per tree were then converted into weight of wet beans per tree.

Selected Trees.

Turning now to the average yield in wet beans over eleven seasons, the first three trees were automatically selected. A further seven were chosen from their general appearance in the field, bearing in mind their position in the order list. Self-fertilised progeny from these ten were planted out in 1933 at Moor Plantation. It is realised that in this first selection insufficient value was being placed on the weight of dry beans. Recent produce regulations (3) demand that one pound of dry beans shall contain not more than 437 beans in order to pass as grade I. Out of the ten selections only four yielded beans to pass this standard. Two of these four Trees No. 38 and 9 are, however, far superior to any of the others with regard to yield and are the two outstanding selections; Tree 38 has given an average of 32.4 lb. of wet cacao over eleven seasons and Tree 9 30.8 lb. over the same period. The 1933 programme, therefore, entailed the self-fertilisation of the original ten and seven additional selections which were chosen largely on account of their bean weights. Seed from all these seventeen trees was required for planting an experimental farm near Ajia. Towards the end of 1933 two selected trees were lost, and to replace these, two additional selections have been made.

Table II gives the yields and main characteristics of those trees which have been or will be used as parents. Over the 1931/32 season a heavy crop was produced. This was particularly fortunate as it enabled the figures in columns 5, 7 and 8 to be obtained with what is considered a reasonable degree of accuracy. But it is possible that in heavy yielding years the weight of beans may decrease, and thus the figures in column 8 may be on the pessimistic side. It should also be remembered that the number of dry beans per pound was obtained from only one harvest.

The preliminary selection which has been described must be regarded as a first step in the development of a high yielding population from which later selections can be made. Nevertheless, should occasion arise, any immediate demand for seed for distribution could be met by utilising Trees 38 and 9. When the self-fertilised progeny of those trees recorded in Table II has been established, it is hoped that there will be some 10,000 trees which will be individually recorded. From a population of this size very valuable material is to be anticipated.

TABLE II.

1	PODS. 2	3	4	5	BEANS. 6	7	8	
Tree No.	Average number per annum 1921/22 to 1931/32	1932/33.	1933/34.	Average weight of 100 Pods.	Average weight per annum 1921/22 to 1931/32	Average weight from 100 pods lb. wet.	Number of dry beans per lb.	REMARKS.
38	129	245	240	105	32.36	25	383	
9	140	275	289	78	30.82	22	392	
95	126	121	148	71	23.96	19	460	
30	106	252	402	80	22.28	21	420	
104	110	141	200	75	22.22	20	466	
75	106	284	285	66	19.10	18	528	
213	95	200	74	69	18.18	19	452	
35	91	177	353	70	18.13	19	464	
53	87	131	199	70	17.42	20	538	
184	93	137	123	64	15.70	17	356	
7	95	121	87	92	22.80	24	351	Fallen over, 1933/34.
13	96	167	201	84	21.48	22	356	
15	81	174	125	82	15.48	19	434	
86	86	139	139	73	17.20	20	426	
108	75	147	215	82	15.75	21	418	
118	70	182	113	74	13.84	20	363	Dying, 1933/34.
162	89	133	81	73	17.90	20	411	
190	70	108	187	82	14.39	21	370	
50	85	123	119	91	14.37	17	396	

SELECTION FOR QUALITY.

Only a few trees on Moor Plantation give rise to the light coloured bean, and these trees occur in the small isolated plots previously mentioned. No yield records had been kept until 1931, and since that year no consistently heavy yielders have come to light. The most productive trees within these plots have the common purple beans.

During the 1931/32 season investigations were carried out on the trees in these plots on lines similar to those which have been described above in connection with preliminary selection of the forty-nine trees. While some of these plots were found to contain trees of no outstanding peculiarity, others exhibited a great diversity of types.

In two plots, where the ancestry is fairly certain, the red pod colour has been transmitted, and no yellow pod types occur in the progeny. Most of these coloured varieties have larger pods than those found on the yellow pod trees, but the larger pod is not necessarily correlated with heavier contents. Thus the average weight of 100 pods from one particular red pod tree was 133 lb., but the weight of wet beans from these was only twelve pounds. As a working basis the Department of Agriculture recognises that, for Nigerian cacao, 100 pods average eighty-six pounds yielding twenty pounds of wet cacao; but this tree, which at first sight attracts attention, actually yields far less cacao, pod for pod, than the common yellow Amelonado. This was accounted for by reduction in the number of beans per pod to nineteen.

In four of the plots a certain number of trees produced light coloured beans, and in one plot every tree did so. The actual proportion of light to purple coloured beans for each tree was not determined, but it was estimated that in no instance did the light coloured beans exceed twenty per cent. In many instances the shape—judged by eye- of these light coloured beans was typical of the Forastero varieties, and had not the plumpness associated with Criollo cacao.

Using the technique described in a former paper (4), an attempt was made in 1933 to self-fertilise flowers from those trees which threw light coloured beans. Investigations had shown that there was little difficulty in obtaining self-fertilised seed from the yellow pod Forastero trees (5), but, although some fifty pollinations were made on these trees with " quality " beans, not a single pod was set. This bears out Pound's theory of incompatibility (6). Further attempts will, however, be made to obtain either self or cross pollinated progeny.

The percentage of very light coloured beans from any one tree was so small that it was not considered advisable to establish a clonal plot even of the best; but through controlled pollination it is hoped that the percentage of light coloured beans might be increased, and then with judicious selection of the best beans—as suggested by Wellensiek in Java (6)—a progressive grading up of quality might be undertaken.

Until this can be accomplished, reliance will have to be placed on introduced material to supply the basis for the improvement of quality. A start on these lines has been made by the introduction of superior strains from Trinidad, which has been made possible through the courtesy of the Director of Agriculture of that Colony and through the valuable assistance of the Director, Royal Botanic Gardens, Kew, in germinating the seed and forwarding the seedlings.

Discussion.

It is clear that in this preliminary selection yield has been considered of the greatest importance, and, should the progeny of the selected trees inherit the productive capacity of their parents, possibilities of a yield per acre double that now produced seem attainable. Apart from yield, attention among the Forastero types has been paid to the size and rounded shape of bean, and this part of the work will receive progressively more attention in the second and subsequent generations. It has been judged to be essential to build on a foundation of heavy yield rather than to propagate trees with superior shaped beans in the hope that high yield would follow later.

There seems no likelihood of those strains which have light coloured beans passing beyond the precincts of departmental farms for many years. They have yet to prove themselves able to withstand Nigerian conditions and to yield sufficiently for comparable profits to be made. In this respect it will be noted that Trinidad cacao sells at approximately twice the price of West African, but the yield per acre of the latter is certainly more than double that of the former; and if Van Hall's figure of 270 lb. per acre (8) for Trinidad is accepted. present experience suggests that Nigerian yield is not less than three times this figure. Thus, in spite of the high quality of Trinidad cacao and of the resulting higher price, the Nigerian farmer already obtains a greater monetary return per acre than is attainable in Trinidad. To consolidate and improve the present high yield—that one characteristic which has placed West African cacao in a pre-eminent position—has been the primary object of this first selection.

Summary.

1. The botanical uniformity of cacao growing in Nigeria has been noted.

2. A brief description of the material available for cacao selection work has been made. The individually recorded trees on Moor Plantation formed the population on which the preliminary selection for yield was based.

3. The yields per acre for these two Moor Plantation plots averaged 812 lb. and 327 lb. of dry cacao over eight seasons. From various causes these yields are considered below the average for native farms as a whole; the Ajia plots (three seasons) give 900 lb. and the Owena (one season) plots 963 lb.

4. The basis of the initial selection was yield. Fifty-two trees which had an average of seventy pods or over through ten seasons, or ninety pods or over through the latter five seasons were marked for further consideration.

5. Three red pod trees which passed the initial selection were discarded. It is hoped that red pod character will eventually be correlated with light coloured bean.

6. During the 1931-32 season the following data were collected for each of the remaining forty-nine selections :—

(*a*) Number of pods.
(*b*) Weight of pods.
(*c*) Weight of wet beans.
(*d*) Number of dry beans per pound. (From one harvest.)

7. Previous yields were then converted from " number of pods " to " weight of wet beans ".

8. The three highest yielding trees were automatically selected; seven from general appearance and an additional nine which had largish beans, were also chosen.

9. The self-fertilised progeny of these trees must be looked on as yielding a population from which further selection will be based.

10. Isolated plots on Moor Plantation disclosed trees which yielded a few light coloured beans. Attempts to self-fertilise the best of these failed.

11. Selection for quality will of necessity be confined to the latter and to introductions.

Acknowledgments.

I am particularly indebted to Mr. E. J. Spiff, who has been responsible for much of the routine work in connection with the collection of data on which the final selection has been made. To Messrs. J. West and A. E. Trotman, for their permission to publish yield figures on native farms, and to Superintendents of Agriculture, who have been in charge of Moor Plantation, for the yield records between 1921 and 1930.

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BLACK POD OF CACAO.

EXPERIMENTAL CONTROL ON NATIVE FARMS.

By J. West, B.S.A.

In 1931, Mr. T. Laycock, formerly Senior Mycologist of this Department, laid down a series of experiments dealing with the control of Black Pod of cacao (*Theobroma cacao* L.) on native farms. Since their inception, three main season crops have been harvested, and the results appear sufficiently interesting to warrant their publication.

Dade, in the Gold Coast (1), has shown what fungi are most commonly responsible for pod diseases and the factors which normally govern their incidence. In the present experiments, the term " Black Pod " has been used throughout to include any form of pod disease, no attempt having been made to confine it to those pods showing infection by *Phytophthora faberi*. Since the object of this experiment was to demonstrate the possibility, or otherwise, of practical control measures, the whole complex of pod diseases has been dealt with empirically.

The experimental plots lie in the neighbourhood of the villages of Orile-Odo and Ajia, on the Ijebu-Ode road some ten to twelve miles to the south of Ibadan. The average Nigerian cacao farm is small and irregular, being broken up by patches of annual crops and bush. Consequently, the selection of typical cacao farms which would lend themselves to experimental work and at the same time afford easy access for frequent supervision resulted in the plots being widely separated and of small size. Through the good offices of the Ibadan Native Administration an understanding was reached with the respective owners whereby the Department would try out various methods of control in one section of each plot, while the other section would be cared for by the farmer All harvesting would be undertaken by the Department, and the wet cacao, after being recorded, would be handed over to the owners. In practice, this method of dealing with the plots has been found to work very well; and the farmers have frequently expressed themselves as being well satisfied.

The plots are rectangular in shape, and are divided into two sections for treatment and control. In March, 1931, each treated section was heavily pruned and thinned out To make the respective treated and control sections equal as to number of stands, additional

trees were taken in to compensate for those cut out in thinning. The treated sections were later re-measured, and all yield calculations are now made on an acreage basis. Table 1 gives briefly the details of each plot. The trees in the plots are typically tall, spindly and closely planted, and they range from ten to twenty years in age.

TABLE 1.

AJIA CACAO PLOTS : DETAILS.

Plot.		Acreage.	Number of Trees.	Trees per acre (Nominal).	Treatment.
I.	Treated ...	0·34	162	477	Bordeaux Mixture Spray.
	Control ...	0·25	162	648	
II.	Treated ...	0·21	96	457	"Cupryl" Copper Dust.
	Control ...	0·20	96	480	
III.	Treated ...	0·47	252	536	"Olite" Sulphur Dust.
	Control ...	0·34	252	741	
IV.	Treated ...	0·89	432	485	Clean Sanitation.
	Control ...	0·78	432	554	

Note :—10′ x 10′ square gives 435 stands per acre.
9′ x 9′ „ „ 537 „ „ „

Humidity and temperature records were kept for the first nine months in Plot IV, using Edney Thermohygrographs. It was found, however, that these self-recording instruments were difficult to maintain in good adjustment and working order, and the practice was discontinued. After the preliminary pruning and thinning out, the humidity in the treated section fell by ten per cent, and the temperature correspondingly increased. These differences, as was to be expected, became much less as the year advanced owing to the pruned trees reforming a good overhead canopy of leaves. By the end of the year normality appeared to have been reached. The heavy pruning resulted for a time in lighter conditions which Mr. Laycock recorded as favouring the presence of *Helopeltis* sp. (2) and *Sahlbergella* sp. Pods from the treated trees suffered much more from attack by these insects than did pods from the control trees. Very little harm, however, appeared to be done to the contents of the pods.

The spray and dusts are applied in March at the commencement of the rains, in June when the rains are pronounced and in August during the short dry season. In 1933 the rainfall showed a twenty-five per cent increase over the previous twenty year average, and no spraying or dusting was done in August owing to the exceptionally wet conditions.

Plot 1 was selected for spraying as it is situated on the slope of a steep valley with a stream close at hand. Two " Four Oaks " knapsack sprayers have been used to apply the Bordeaux Mixture 4-4-50 spray at the rate of about 200 gallons per acre. Recently, however, two " Four Oaks " bucket type sprayers have become available. These machines have a double action pump fixed to the bucket, are easily carried by two men, and throw a very efficient spray. They will be used this year, and should reduce the costs of spraying considerably.

The dusting has been done with two knapsack bellows machines, which have proved to be unsuited for cacao work since they cannot blow the dust out of the nozzles with any force. An " Early Bird " rotary duster supplied by Messrs. Craven and Co., Evesham, is now being tried out with considerable promise of success. In Plot II " Cupryl " copper dust is used and in Plot III " Olite " sulphur dust, both being proprietary brands supplied by Messrs. Craven and Co. The dusts are applied so as to cover the trees thoroughly, the rate being about 120 lb. per acre. In common with experience in other countries, it was found that the dusts were easier to apply but that the spray was more adhesive. The clean sanitation practised in Plot IV consists of the removal and burial at frequent intervals of all black pods and the burial of pod husks.

As a routine, the treated sections of all plots are pruned of dead wood once a year, and periodically all chupons are removed and all bush growths are cutlassed.

As already mentioned, the plots were given their first treatments in March, 1931. Yield records were commenced with the main crop of 1931-32. At each harvest, the healthy and black pods from each treated and control section are counted. The pods are then broken and the weights of good and diseased wet cacao recorded. The figures in Table 2 represent the percentages of black pods and those in Table 3 of diseased wet cacao by weight for the main and mid season crops.

TABLE 2.

AJIA CACAO PLOTS : PERCENTAGES OF BLACK PODS FOR MAIN AND MID-SEASON CROPS.

Plot.	1931–32.		1932–33.		1933–34.
	Main.	Mid.	Main.	Mid.	Main.
I. Bordeaux Mixture ...	5·0	2·9	5·4	4·6	12·2
Untreated	20·9	2·2	17·4	20·1	3·6
II. Copper Dust	14·2	5·1	5.4	3·4	4·4
Untreated	26·5	4·8	11·4	9·5	5·7
III. Sulphur Dust	12·0	4·6	5·4	22·7	9·6
Untreated	17·9	3·1	23·1	62·1	18·9
IV. Clean Sanitation ...	8·8	5·9	10·4	5·8	4·8
Untreated	8·2	6·9	11·2	6·2	3·6

TABLE 3.

AJIA CACAO PLOTS : PERCENTAGES OF DISEASED WET BEANS BY WEIGHT FOR MAIN AND MID-SEASON CROPS.

Plot.	1931–32.		1932–33.		1933–34.
	Main.	Mid.	Main.	Mid.	Main.
I. Bordeaux Mixture ...	3·4	1·0	2·2	2·6	4·6
Untreated	6·2	1·9	10·8	10·0	2·3
II. Copper Dust	8·1	2·9	2·7	—*	1·2
Untreated	12·4	3·4	5·4	—*	3·2
III. Sulphur Dust... ...	5·2	2·4	3·2	2·6	3·8
Untreated	8·2	1·6	10·3	1·6	8·1
IV. Clean Sanitation ...	3·8	4·6	5·5	2·4	2·1
Untreated	4·1	3·9	4·7	2·8	2·5

* Fractional values only.

It will be seen that, in general, a reduction in the incidence of disease has been effected by the spraying and dusting, more especially in the main season crops. The rise in the percentage of disease in the sprayed section of Plot I and the corresponding fall in the control section in 1933-34 is difficult to explain. The treated section lies

lower on the slope and nearer the stream than the control, and it is possible that the non-application of the August spray in 1933 may account for the rise in the incidence of infection.

The methods of clean sanitation adopted in Plot IV have naturally shown no striking results. The plot as a whole gives a much cleaner crop than do the others, as is shown in Tables 2 and 3. For the first eighteen months, the control section showed slightly less disease than did the treated. This may be due to the fact that, before the plot was taken over for the experiment, the breaking of pods was carried out in the middle of the treated section, although Dade (loc. cit.) has not found heaps of husks to be a likely cause of infection.

It is difficult to evaluate the efficiency of Bordeaux Mixture against the copper and sulphur dusts. In Table 4 are given the percentages of black pods and diseased beans for the combined crops harvested from September, 1931, to February, 1934.

TABLE 4.

AJIA CACAO PLOTS : PERCENTAGE OF BLACK POD AND DISEASED BEANS FOR THE PERIOD 1931-34.

Plot.	% Pods Diseased.	Reduction.	% Beans Diseased.	Reduction.
I. Bordeaux Mixture ...	6·6	6·7	2·9	3·3
Control	13·3	—	6·2	—
II. Copper Dust	8·0	7·1	4·3	2·8
Control	15·1	—	7·2	—
III. Sulphur Dust	9·5	12·1	3·8	5·0
Control	21·6	—	7·9	—
IV. Clean Sanitation	7·8	0·1	4·0	0·0
Control	7·9	—	4·0	—

The percentage of black pods harvested in each control section can be taken as the index of the potential infection within the plots. There is a fairly close agreement in the percentages of infection for the treated sections in Plots I, II and III, and between the control sections of Plots I and II. Plot III has a higher potential infection, and shows a greater reduction for sulphur dusting than do the other two plots for copper dusting or Bordeaux Mixture spraying. At the same time, the figures also suggest that both dusts and spray have reduced the amount of infection to a fairly common level. The percentages of beans diseased naturally depend on the regularity of

harvesting, a point referred to later. Since harvesting in these plots is practically simultaneous, the percentages might indicate the degree as opposed to the amount of pod infection, in which case the spray has been slightly less effective than the two dusts. It is very apparent that Plot IV is comparatively clean, and that, in consequence, the sanitary measures have had no effect so far.

In estimating the amount of disease, consideration must be given both to black pods and diseased beans. A pod may show infection of the husk, while the beans within may be completely healthy or only partly diseased. Consequently the amount of diseased beans depends very largely on the regularity of harvesting.

TABLE 5.

AJIA PLOTS : PERCENTAGES OF BLACK PODS AND DISEASED BEANS OF THE CONTROL PLOTS FOR THE PERIOD 1931-34.

Plot.	Percentage Black Pods.	Percentage Beans Diseased.
I. Control	13·3	6·2
II. Control	15·1	7·2
III. Control	21·6	7·9
IV. Control	7·9	4·0

Table 4 shows that in all cases the proportion of diseased beans is considerably lower than the proportion of diseased pods. The greater the periods between harvests, the more closely would these proportions approximate. Referring to Table 5, it will be seen that, in the normal conditions as represented by the control portions of each plot, the difference between the percentage of pods diseased and of beans diseased ranges from roughly one-half to one-third. Dade (loc. cit.) found that although about seventy per cent. of the crop reaped was diseased, only about four per cent. was lost by the farmer.

As already explained, the treated portion of each plot, when first taken over, was heavily pruned and thinned out. The object of this was to give each tree a further chance for development. The total yields from each plot, including both healthy and diseased material should show to what degree pruning and thinning have effected the yield capacity of each treated portion. In Table 6, the total yields of both healthy and diseased beans are expressed in pounds of dry cacao per acre.

TABLE 6.

AJIA PLOT YIELDS : TOTAL WEIGHTS OF BEANS, HEALTHY AND DISEASED, EXPRESSED AS LB. DRY CACAO PER ACRE.

Plot.	1931-32.		1932-33.		1933-34.	Total Yield, 1931-34.
	Main.	Mid.	Main.	Mid.	Main.	
I. Bordeaux Spray ...	521	249	874	292	579	2,515
Control	552	267	587	86	444	1,936
II. Copper Dust ...	940	215	766	92	504	2,517
Control	916	125	959	110	467	2,577
III. Sulphur Dust ...	1,354	388	1,256	318	711	4,027
Control	1,484	317	1,293	235	295	3,624
IV. Clean Sanitation ...	797	357	794	140	585	2,673
Control	969	226	662	97	395	2,349

Total yield of four treated plots ... 11,732
Total yield of four control plots ... 10,486

Increase in favour of treatments ... 1,246
Average increase per plot 312 lb. dry cacao per acre.

With the exception of Plot II, the main crop of 1931-32 was reduced by the pruning. There was a general tendency for the following mid-season crop to be higher in the treated plots, and this increased rate of yielding has been more or less maintained since. The main season crop of 1933-34 was a poor one in the Ajia area, but, while all yields were down, those of the control plots were relatively much more so than those of the treated. This may be due to the better conditions under which the treated trees are now growing. If the gross yields for 1931-34 are added, as in Table 6, there is an average total increase for the treated plots of 312 lb. of dry cacao per acre per plot. Although not statistically significant, this figure expresses the stimulation which has resulted from the original pruning and thinning. In Table 7, the weights of healthy beans harvested are expressed as pounds of dry cacao per acre.

TABLE 7.

AJIA PLOT YIELDS: WEIGHTS OF BEANS, HEALTHY ONLY, EXPRESSED AS LB. DRY CACAO PER ACRE.

Plot.	1931–32.		1932–33.		1933–34.	Total Yield 1931–34.
	Main.	Mid.	Main.	Mid.	Main.	
I. Bordeaux Spray ...	504	247	856	286	553	2,446
Control	518	261	523	77	433	1,812
II. Copper Dust	864	209	745	92	498	2,408
Control	802	120	907	110	452	2,391
III. Sulphur Dust	1,284	379	1,216	309	683	3,871
Control	1,362	312	1,160	231	271	3,336
IV. Clean Sanitation ...	767	340	750	136	561	2,554
Control	929	217	631	94	385	2,256

Total yield of four treated plots ... 11,279
Total yield of four control plots ... 9,795

Increase in favour of treatments ... 1,484
Average increase per plot 371 lb. dry cacao per acre.

If these figures are totalled as in Table 7, the average increase for the treated section of each plot has been 371 lb. of dry cacao per acre over the period 1931-34. Although again not significant, this figure expresses the influence of both the pruning and thinning and also of spraying and dusting. Over the same period the sanitary measures carried out in Plot IV have not had the same effect, as will be seen by comparing the increase for this plot in Table 7 with that in Table 6. At the same same time it must be remembered that Plot IV is exceptionally free from disease, and a more favourable result would probably be obtained were the potential incidence of disease higher.

The costs of the various treatments are expressed below on an acreage basis. It is extremely difficult to assess these costs accurately because experiments of this nature are bound to be much more expensive than similar operations carried out on a practical scale.

Original pruning and thinning out, and general clean up of the plots = 73 man-days per acre.
Spraying (per application) = 6 man-days per acre.
Dusting (per application) = 10 to 11 man-days per acre.

The original pruning and thinning out was such an expensive operation because a considerable amount of time was expended in trying out various methods. It was found to be most difficult to obtain a minimum of atmospheric humidity, thus reducing the conditions suitable for pod infection, without causing injury to the trees. The trees range from ten to twenty years in age and, being closely planted, had tall spindly trunks and a canopy of densely interlocked branches overhead. That mature trees should have responded so well to this treatment and maintained their response suggests that the methods finally adopted were sound.

To the labour costs of applying the sprays and dusts must be added the outlay for machines (£4 to £5 apiece) and for material (at least £1 per cwt. for the dusts). When these points are considered, it becomes obvious that spraying and dusting are not yet economic methods of control. Dade, (loc. cit.) using much smaller quantities of dust at each application, estimated a cost of just over £3 per acre, and he concludes that only with dusts having better adhesive qualities and an improvement in market conditions will dusting become an economic possibility.

The point to be remembered about these experiments is that the treatments have been carried out on mature cacao. That farms which have suffered the normal native methods of cultivation for from ten to twenty years should have shown the responses obtained at Ajia suggests that the control of black pod disease is not economically impossible. It is not suggested that pod diseases can be wiped out, but if their incidence can be reduced to a reasonable level, and if at the same time the yields per acre are increased, the farmer would derive considerable benefit. And there does not seem to be any great doubt about the obtaining of such conditions, provided the farmer gives his cacao a wider spacing and cares for the young trees from the beginning. In this connection it is of interest that several farmers at Ajia copied the pruning and thinning which had been carried out in the experimental plots. Where this was done in young cacao the benefits should be obvious. And even where it is done in mature cacao, the results from the experimental plots suggest that, provided the trees are sound, the response is not transitory. Finally, if the farmer harvests as frequently as is economically possible, he should reduce his losses due to disease to a much lower level without having recourse to spraying or dusting. Naturally, at present, he is discouraged by the low cacao prices prevailing.

Summary.

Experiments on the control of Black Pod Diseases of cacao on native farms in the Ibadan area during the past three years are described.

Spraying with Bordeaux Mixture and dusting with "Cupryl" Copper and "Olite" Sulphur three times a year have been found to reduce the amount of diseased cacao. The costs of machinery and materials have proved so high and the resulting increase of good cacao so low that spraying and dusting have thus far proved to be uneconomic methods of disease control.

Removal and burial of black pods at frequent intervals did not result in a reduction of the disease incidence, but the plot in which this clean sanitation was carried out was remarkably free from disease as compared with the other plots.

Although the farms were from ten to twenty years old, pruning and thinning the trees out to a better spacing have resulted in an increase of yield which has been maintained.

Regular harvesting at fairly frequent intervals was found to be one of the most promising methods of preventing loss from disease, since, although the pod husk may be infected, the beans within will be healthy if the pod is harvested in time.

It would appear that the native farmer might expect both increased yields and less disease if he would plant his cacao at a wider spacing, prune and generally care for the trees and harvest regularly.

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Appendix.

The data obtained from these experiments are of interest in that they give an indication of the conditions existing in native farms round Ibadan. The figures in Table I show a variation of from 480 to 741 trees per acre in the control sections. Dade (loc. cit.) gives 335 to 580 trees to the acre for the native farms in which he was working at Anyinam, a wider spacing than that which appears to be typical round Ibadan.

As regards the average yields obtained from mature trees in this area, the control plots show a considerable variation in lb. of dry cacao per acre.

	1931-32.	*1932-33.*	*1933-34*
Plot I control	779	600	433
Plot II control	922	1,017	452
Plot III control	1,674	1,391	271
Plot IV control .. .	1,146	694	385
Average (1.57 acres)	1,173	886	376
Moor Plantation Yellow Pod (2.22 acres)	1,102	774	846

The 1933-34 figures are for the main season crop only, but even so, they show that the season was a very poor one. Dade gives an average of 1,335 lb. dry cacao per acre for the Anyinam farms, the increase possibly being due to the wider spacing existing on these farms. The figures for the Yellow Pod cacao on Moor Plantation (Voelcker, (3)) bear out the fact that cacao yields in both the 1932-33 and 1933-34 seasons were lower than in previous years.

Voelcker (loc. cit.) gives 20 lb. of wet cacao as the normal product from 100 pods for main season crops. The values for the Ajia plots for 1931-34, including both healthy and diseased pods and beans are as follows :—

Main season—three crops.
93,283 pods gave 18,880.5 lb. wet cacao.
i.e., 100 pods≡20.2 lb. wet cacao.

Mid season—two crops.
21,521 pods gave 3,709.25 lb. wet cacao.
i.e., 100 pods≡17.22 lb. wet cacao.

All season—five crops.
114,804 pods gave 22,589.75 lb. wet cacao.
i.e., 100 pods≡19.7 lb. wet cacao.

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